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SOVIET SOIL SCIENCE

11

NOVEMBER 1961

A TRANSLATION
OF POCHVOVEDENIYE

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THE translation and publication of this and other Russian language biological journals and monographs is a project of the American Institute of Biological Sciences. This project is supported by grants from the National Science Foundation. Each publication is a cover-to-cover translation of its Soviet counterpart and the contents are only those of the original authors.

Pochvovedeniye in English translation bears the Soviet issue numbers. The Soviet journal carries no volume numbers. Translation begins with Number 1, the January 1958 issue. It is published in the same number of issues per year as the original Soviet journals: 12 issues.

translated and produced by
scripta technica, inc.

Subscription Prices:
$40.00 per year, individuals and industrial libraries
20.00 per year, AIBS members and all other libraries
3.00 additional to each price for foreign orders
4.50 each, single copies

Order from:

American Institute of Biological Sciences
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SOVIET SOIL SCIENCE

A translation of the monthly journal—POCHVOVEDENIYE—
a publication of the V. V. Dokuchayev Institute of Soil Science,
Academy of Sciences, USSR. A journal founded in 1899.

Pochvovedeniye Editorial Board: I. V. Tyurin (editor-in-chief), I. N. Antipov-Karatayev, N. I. Gorbunov, K. P. Gorshenin. A. A. Zavalishin, V. N. Zavaritskii, S. V. Zonn (assistant editor), O. K. Kedrov-Zikhman, V. M. Klechkovskii, V. A. Kovda, M. M. Kononova (assistant editor), Ya. V. Peive, I. I. Sinyagin, A. V. Sokolov

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No. 11, November 1961 Translation printed: July 1962

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COMPONENT WATER OF THE GEOGRAPHICAL ENVELOPE

V. R. VOLOBUYEV, Institute of Soil Science and Agricultural Chemistry, Academy of Sciences, Azerbaydzhan SSR

The distribution of atmospheric precipitation at the earth's surface is usually considered by assuring that a considerable amount of precipitation is used in total evaporation (evaporation from the soil surface and transpiration), and that the rest flows into rivers and later into oceans in the form of surface and subsurface runoff. This concept is expressed in the standard water balance equation

$$\underline{P} = \underline{E} + \underline{f}, \qquad (1)$$

where P is the amount of precipitation, $\underline{E}$ is total evaporation, and $\underline{f}$ is total runoff.

In other words, the transformation of water at the earth's surface is considered as a closed cycle.

This concept is justified in practice in the hydrological sense, but it is not satisfactory for the geographical envelope as a complex structure. The moistened layer of soil and soil materials and vegetation are considered thereby only as some receptacles or conductors of circulating water. It becomes clear that such a concept does not agree with the idea of the development of the geographical envelope as a process of qualitative changes. Equation (1) does not include any quantitative parameters which would reflect the development of this process. Consequently, it does not completely express the water cycle in the geographical envelope.

When studying soil-climatic relationships it was found that soils can be grouped according to their moisture into seven hydrological series — from soils in areas of extremely low moisture to the most wet soils. The climatic conditions of each hydrological series are characterized by a very definite correlation between the annual amount of atmospheric precipitation (P) and the radiation balance of the earth's surface ($\underline{R}$), which obeys the relationship

$$0.67 \log \underline{R} = \log \underline{LP} - \log \underline{LP_k} \qquad (2)$$

where $\underline{L}$ is the latent heat of vaporization and $\underline{P_k}$ is a value which is constant for each hydrological series (if $\underline{P}$ is in mm then $\underline{P_k}$ is also in mm).

Since we know that the degree of relative humidity is determined by the relationship between the amount of atmospheric precipitation and available heat sources, relationship (2) must be considered as representing the general principles of this relationship. The assumption that relationship (2) reflects the natural processes of evaporation is confirmed by the results of soil hydrological investigations, which showed that maximum natural evaporation (natural normal evaporability $\underline{En}$) is related to the radiation balance at the earth's surface by

$$\underline{En} = 49\, \underline{R}^{0.67} \qquad (3)$$

In relation to all of this the idea occurred that the constant $\underline{P_k}$ in the foregoing relationship (2) can be interpreted as a certain amount of atmospheric precipitation which does not participate in evaporation. This is that part of total annual precipitation which becomes bound in the substances composing the geographical envelope, or, in other words, in biogeocoenotic substances.

In fact, we know of the great role of water in nature and that water in one or another form participates in all the processes taking place in the earth's core. Therefore, it is evident that we cannot limit ourselves to the concept of a closed hydrological cycle. At certain stages of the hydrological cycle reactions of the irreversible type occur in nature (at least for a certain time), when a certain part of the water from atmospheric precipitation is bound in a substance, formed with the participation of water molecules. Only under this condition is the concept valid that the hydrological cycle is a varied natural process, in which, in addition to cyclic reactions, reactions of the irreversible type take place, which lead with time to certain qualitative changes.

From the moment when a rock is brought to the surface by tectonic forces and begins to be subject to atmospheric and biological agents, the process of its transformation proceeds not only in the direction of shattering, but also in the direction of every increasing hydration of the residual products of weathering. The soluble components become involved in the formation of a vegetable substance rich in water, whose mass will ever increase as it develops. Thus, in its broad sense, the process of rock weathering with the participation of biocoenosis can be considered as the process of the involvement of every increasing amounts of water in the formation of new components of the weathering crust.

The main links in the chain of the development of the hypergenic envelope, and in the chain of the states and transformations of water in it, are the following two: the state of fresh igneous rocks, containing the least amount of water, and the state of substances very rich in water in the uppermost zone of the earth's crust, represented by various types of biogeocoenoses, i. e, interrelated soil materials, soils, plant and animal communities, and adjoining layers of the atmosphere. Let us call the water which is involved in the formation of mineral and organic substances, joined and interrelation soil materials, soils, and vegetative and animal organisms, component water (h).

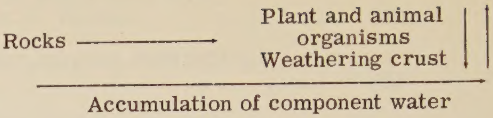
First of all we must determine the composition of component water, i. e., examine which types and states of water in nature conform to the concept of component water. Component water is bound, immobilized water. Therefore, it is evident that the flowing water on the earth's surface (the water of rivers and streams), as well as the water of surface reservoirs, cannot be considered as component water. The gravity water of soils and soil materials, which is in motion, cannot be considered part of component water either, since it moves beyond the limits of a given biogeocoenosis with time. But we have all the reasons to consider as component water all the water which is retained by the soil and soil material by film-capillary forces. The capacity to retain free water is a property which develops during the process of weathering and soil formation. Water in the permanently frozen layers of the soil must also be included here.

Hygroscopic and the so-called chemically-bound water, hydration, crystallization, and constitution water must also be considered as component water.

In the biologically bound part of component water we must consider first of all water which saturates organic substances: the tops and roots of plants, animals, and their dead remains. But at the same time we must also consider that water which was used to form organic matter — carbohydrates. We must also consider water forming part of humic compounds.

Thus, component water includes water in the following forms and states: film and capillary water in soils and associated soil materials; hydroscopic, hydration, crystallization, and constitution water in the mineral compounds of the weathering crust; the water in the living plasma of plants and animals; water saturating dead plant and animal remains; water in the carbohydrate molecules of plants and animals; and water in humic compounds.

The process of accumulation of component water can be represented schematically in the following form:



In conformity with the concept of the intensity of processes of the development of the geographical envelope, we can judge of its biogeocoenosis by the total amount of water involved in the formation of new substances (mineral and organic), if, of course, we know the duration of the formation of the biogeocoenosis and of the process of transformation of the weathering crust. Another criterion of the intensity of this process is the annual increment of water. Knowing the magnitude of the latter, as well as the total amount of water accumulated in biogeocoenotic substances, we could approximately determine the duration of the process of the biogeocoenosis formation.

Even though it is difficult to characterize the intensity or depth of expression of the development process of the geographical envelope by determining the total amount of water involved in the formation of the components of biogeocoenosis, it is still possible if we compare materials of similar age. The latter is apparently possible, under certain assumptions, of course.

As far as the second possibility is concerned, i. e., that of characterizing the intensity of weathering on the basis of the magnitude of the annual increment of water in biogeocoenotic substances, there is only one possible way for the time being, that of using P_k, i. e., that amount of total annual atmospheric precipitation which is annually bound in newly-formed biogeocoenotic substances.

Let us examine P_k from this point of view. P_k changes with moisture conditions in the following manner:

Moisture zones according to the hydrothermal system		$K=\frac{\text{precipitation}}{\text{evapor. (En)}}$	P_k, water layer, mm/year
Extremely dry	A, AB	<0.20	<0.12
Dry	B, BC	0.20-0.40	0.12-0.22
Moderately dry	C, CD	0.40-0.75	0.22-0.36
Moderately moist	D, DE	0.75-1.20	0.36-0.62
Moist	E, EF	1.20-1.95	0.62-0.95
Very moist	F, FG	1.95-2.90	0.95-1.39
Especially moist	G	>2.90	>1.39

As mentioned earlier, P_k is constant under the conditions of each hydrological series. Therefore, since we decided to consider it as the amount of water which is annually additionally involved in the formation of new substances in the geographical envelope, the following question arises: how can we take one and the same amount of involved water independently of temperature conditions, such as conditions in the tundra and tropics (with a similar degree of relative wetness of course)? This assumption is correct, since the increment of water must be considered as being dependent first of all on relative wetness.

The validity of this assumption as the possibility of interpreting P_k as the amount of precipitation which is bound in the substance of biogeocoenosis, apparently can be verified by comparing the total amount of component water accumulating under various moisture conditions with P_k for the same conditions. In order to do this we must have data on natural materials formed under various conditions.

It is quite clear that the first stage of such a study will be of a schematic, approximate nature and methodical to a high degree. Therefore, in the study undertaken by us we do not characterize definite natural materials, but their zonal types.

The first determination of the quantitative values of the foregoing components of component water was made on the basis of typed biogeocoenoses according to zones: tundra, podzolic-taiga, moist tropical, steppe, dry steppe, and sierozem.

Table 1

Experimental calculations of the amount of water accumulated in the mineral and organic components of the geographical medium (component water – h), taking characteristic zonal biogeocoenoses (in the upper 3 m of soil and soil materials and vegetative matter) as an example

Zonal type of biogeocoenosis	Capillary and film water	Hydration water (min. and organic compounds)	Structural water of humus	Water in vegetative matter	Structural water of vegetative matter	Total	Capillary and film water	Hydration water	Structural water of humus	Water in vegetative matter	Structural water of vegetative matter	Total
Tundra	1005	115	7	0,6	0,1	1128	89,1	10,2	0,6	0,05	0,003	100
Poszolic-taiga	1020	88	5	19	4	1136	89,8	7,7	0,4	1,6	0,35	100
Moist tropical	780	441	7	95	20	1343	58,1	32,8	0,5	7,1	1,5	100
Steppe	720	180	15	3	1	918	78,4	19,6	1,6	0,3	0,1	100
Dry steppe	600	75	6	2	1	684	87,7	11,0	0,9	0,3	0,1	100
Sierozem	450	140	3	1	1	595	75,6	23,5	0,5	0,2	0,2	100

Note: Comma represents decimal point.

The calculations were made for the upper 3 meters of soil. The assumption of a layer of the same thickness for all zones is evidently conditional, but it was justified by the requirement that the obtained data be as comparable as possible.

The values of individual composition of component moisture were determined on the basis of the following data and considerations. The content of capillary and film water was taken approximately as the average from data on the dynamics of moisture (minus hygroscopic water). The data were taken from various authors: from Polyntseva (8), Sumgin (11), and P'yavchenko (9) for the tundra zone; Rode (10) and Vasil'yeva (3) for the podzolic-taiga zone; Mohr (13) for the moist tropical zone; Zonn (5) and Mina (7) for the steppe zone; and Bol'shakov (2) for the sierozem zone. Averages from data on the steppe and sierozem zones were taken for the dry steppe zone.

The average hygroscopic water and ignition losses used for the corresponding soils were obtained from an analysis of numerous data available in the literature. The content of CO_2 in carbonates used was taken from a previous analysis (4), and the humus content was taken from the data of Tyurin (13), increased by 20% since in our calculations we took instead of the 1 m of soil, for which the data of I. V. Tyurin were calculated, a 3-m layer, which contains a certain amount of humus.

The total amount of vegetation was taken from the data of Lavrenko (6), Aleksandrova (1), and others. Difficulties arose during the determination of the amount of vegetation under moist tropical

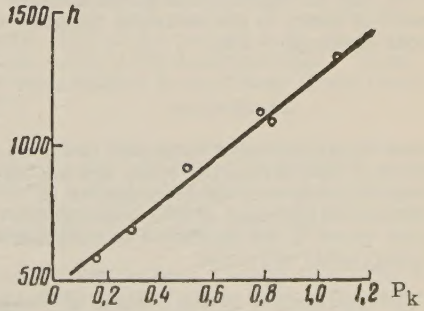


Fig. 1. - Approximate relationship between component water (h), according to the table 1, and P_k, according to hydrological data.

conditions, for which data are scarce in the literature. For these conditions we took the 5-fold amount of vegetative mass in the taiga zone.

To determine the amount of water in the vegetative mass we assumed the moisture of the latter to be 70% for forest and tundra vegetation and 60% for steppe vegetation (6). The water used for the formation of the carbohydrates in the organic substance of plants was assumed to be 50% of its dry weight. For a similar calculation for humus we took 30% of its weight.

The water content was calculated in mm of water layer in all cases.

The summation of the values which comprise component water for the zones under study is presented in Table 1. The data in this table are representative in many respects. Firstly, they show the gradual increase of component moisture from dry to moist zones. Secondly, in moist zones (tundra, podzolic-taiga, and moist tropical) component moisture is approximately the same, from 1100-1300 mm. Consequently, the first assumption, that under similar moisture conditions the same amount of component water accumulates, is confirmed.

The comparison of the total content of component water with $\underline{P_k}$ is even more interesting. As we can see from Figure 1, there is a direct relationship between these values. This allows us to conclude that $\underline{P_k}$ correctly reflects the relative order of the change in the annual amount of atmospheric precipitation being bound from zone to zone. The absolute value of $\underline{P_k}$ is apparently also real. In fact, by dividing the total amount of component moisture by $\underline{P_k}$, we obtain the time it took the found content of component water to accumulate — about 1500-2000 years. If we assume that soil develops on drifts, i. e, that the parent material of the soil has already been enriched with the hydrates of mineral compounds and has a certain water capacity, and divide the time found by two, we obtain the time of soil formation — 750-1000 years. Both periods of time correspond to our concepts of the rate of soil formation. Consequently, there is reason to consider the absolute value of $\underline{P_k}$ as real.

The $\underline{P_k}$ can be represented as the annual increment of water in the bodies of the geographical envelope — $\Delta \underline{h}$.

Conclusions

1. One of the essential elements in the development of the weathering crust and associated biogeocoenoses is the involvement of ever increasing amounts of atmospheric precipitation water in the formation of substances of the geographic envelope.

2. The introduction of the concept of component water as water accumulated in biogeocoenotic substances, such as in soil materials, soils, and plant and animal organisms (bound and saturating), has been justified.

3. As a result of this, the determination of the total volume of component water can serve for the comparative characterization of the intensity of the development of biogeocoenoses.

4. A comparison of the total amount of component moisture with its annual increment under given climatic conditions, i. e., $\Delta \underline{h}$ ($\underline{P_k}$), gives a certain idea of the duration of soil formation.

5. The general formula for the water balance of the geographical envelope should be taken in a more complete form:

$$\underline{P} = \underline{E} + \underline{f} + \Delta \underline{h}. \qquad (4)$$

Received July 14, 1961

BIBLIOGRAPHY

1. ALEKSANDROVA, V. D. 1958. Experimental determination of the above-ground and underground mass of vegetation in the arctic tundra. Botan. zh. No. 12.
2. BOL'SHAKOV, A. F. 1950. Water regime of dry-farmed soils in Uzbekistan. Tr. Pochv. in-ta im. V. V. Dokuchayeva Akad. Nauk SSSR, Vol. 32.
3. VASIL'YEV, I. S. 1950. Water regime of podzolic soils. Tr. Pochv. in-ta im. Vol. 32. Materials for the study of the water regime of soils.
4. VOLOBUYEV, V. R. 1953. Soils and climate. Izd. Akad. Nauk AzerbSSR. Baku.
5. ZONN, S. V. 1959. Soil moisture and forest plantations. Izd. Akad. Nauk SSR.

5a. CRAFTS, A., H. CARRIER, and K. STOCKING. 1961. Water and its role in the physiology of plants. IL, Moscow. (This is a U. S. book printed in the Soviet Union, Ed.)

6. LAVRENKO, YE. M. 1955. Study of the productivity of the tops of the vegetative cover. Botan. zh. No. 3.
7. MINA, V. 1954. Interaction between woody vegetation and soils in certain types of oak forests in the southern forest steppe. Tr. In-ta lesa Akad. Nauk SSSR. Vol. 15.
8. POLYNTSEVA, O. A. 1952. Physical properties of soils of the tundra group. Tr. Komi fil. Akad. Nauk SSSR, ser. geogr. No. 1.
9. P'YAVCHENKO, N. I. 1957. Growing conditions of woody vegetation at its northern boundary. Tr. In-ta lesa Akad. Nauk SSSR. Vol. 36.
10. RODE, A. A. 1937. The process of soil formation. Izd. Akad. Nauk SSSR.
11. SUMGIN, M. I. 1931. Permafrost. Izd. Akad. Nauk SSSR.
12. TYURIN, I. V. 1937. Organic substance of the soil. Sel'khozgiz.
13. MOHR, E. C. 1944. The soils of equatorial regions with special reference to the Netherlands East Indies. Michigan.

NEW MATERIALS ON THE GENERAL GEOGRAPHY AND CLASSIFICATION OF SOILS IN THE POLAR AND BOREAL BELTS OF SIBERIA[1]

YE. N. IVANOVA, N. N. ROZOV, A. A. YEROKHINA, N. A. NOGINA, V. A. NOSIN, and K. A. UFIMTSEVA

Our soil scientists began to study the soil of Siberia only at the beginning of this century, after the modern genetic soil school has been established on the basis of materials for the European part of our country, primarily the Russian plain. Individual stages of the development of these studies are described in a number of soil-cartographic summaries, which reflect the concepts of the gensis and classification of soils, their spatial distribution, and geographical patterns.

The first outline of the soil zones of Siberia was published by K. D. Glinka in 1913 on the basis of the preliminary generalization of materials collected by the soil-geographic zones, established by V. V. Dokuchayev and N. M. Sibirtsev for the European USSR, are extended to Siberia, without regard to the specificity of their soil. There are not enough actual data to do this at that time.

The second soil-cartographic summary of the same materials of the Immigration Office, but on a larger scale (1:4, 200, 000), was compiled by L. I. Prasolov, S. S. Neustruyev, B. B. Polynov, and N. I. Prokhorov during the construction of the soil map of the Asiatic USSR in 1926-1927. It was a further refinement of the zonal outline with more detailed subzonal subdivisions in the steppe zone, and certain individual details of a provincial nature (deeply podzolic soils of the Altay chern' (black), slightly podzolic soils of the mountain regions of Eastern Siberia, solodized soils of the depressions of Yakutiya, etc.).

The third soil-cartographic summary of materials on Siberia was made by L. I. Prasolov on a smaller scale (1:15, 000, 000) and published in 1937 in the "Great Soviet Atlas of the World" on the soil map of the USSR. In this outline the southern limit of tundra soils is defined, the contours of mountain-tundra soils are more accurate, mountain soils are differentiated from similar soils in the plains as individual soil groups.

The fourth summary of soil-cartographic materials for the whole of Siberia is the 1:4, 000, 000 soil map of the USSR, published by the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR and the Main Administration of Geodesy and Cartography in a series of maps of the natural conditions of the USSR.[2] This map was compiled on the basis of extensive soil-cartographic materials on Western and Southern Siberia, generalized in the works of K. P. Gorshenin, materials of N. V. Nikolayev and others on Eastern Siberia, and the new papers of V. G. Zol'nikov on the Far East and of Yu. A. Liverovskiy, A. I. Kachiani, and others on Kamchatka. The 1:4,000,000 geobotanical map of the USSR, edited by Ye. M. Lavrenko and V. B. Sochava, and new hypsometric data and geological materials were of great importance.

The 1956 soil map of the USSR shows the areas of distribution of certain new soils, the change in view of the genesis and classification of certain soils, and reflects a number of recently-discovered geographical patterns in soil distribution. For the first time for Siberia podzolic soil zones are subdivided into subzones with subgroups of gley-podzolic soils of the northern taiga (with surface gleyzation), actual podzolic soils of the central taiga, and sod-podzolic soils of the southern taiga. These soils were studied in the Trans-Urals region (20, 17).

It has been discovered that in the extracontinental regions of Siberia the podzolic process attenuates with the distribution of permafrost and that peculiar soils form, which have been called "pale-yellow sod-forest" soils (8).

Meadow-chernozem, usually solonetzic soils (6) are distinguished as an individual automorphic-hydromorphic group in the flat, undrained interfluves of the forest-steppe zone of the West Siberian lowland. These soils are called "solonetzic soils" in the works of K. P. Gorshenin. They are characterized by the shallow location of ground waters (3-5 m), as well as by a special water and thermal regime. Peculiar sod soils are distinguished in the Kamchatka Peninsula, which form under stony birch stands and on volcanic ash.

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[1] The text of the paper was written by Ye. N. Ivanova and N. N. Rozov, it includes the manuscript materials of L. P. Budina, I. V. Vishnevskaya, I. P. Gerasimov, N. A. Karavayeva, I. T. Kosheleva, Ye. M. Naumova, Ye. V. Semina, I. A. Sokolov, T. A. Sokolova, and V. O. Targul'yan, who thus are the co-authors of the corresponding sections.

[2] This map was compiled by N. N. Rozov in collaboration with Ye. V. Lobova (desert zone) and edited by I. P. Gerasimov (1954, 1956).

The fifth, present stage of the study of Siberian soil is associated with the work of numerous soil institutions and Chairs of institutions of higher learning in Siberia, studies by institutes of the Siberian Branch and large complex expeditions of the Academy of Sciences of the USSR (to Yakutiya, Tuva, Buryat-Mongolia, Krasnoyarsk, Chita, Amur, and Kamchatka), new investigations by the V. V. Dokuchayev Soil Institute in the Far North, and with the compilation of a State Soil Map of the USSR.

The first results of this work are generalized in the recently published 1:10, 000, 000 soil map of the USSR,[3] which shows the general facies differentiation of Siberian soil.

As work on the soil-geographic regionalization of the USSR has shown, three soil-bioclimatic belt can be distinguished at the present time in Siberia (polar, boreal, and sub-boreal) and a number of large soil-climatic regions, having their own zonal soil groups, as well as intermediate facies and provincial groups of soils.

The present paper represents the first, incomplete attempt to generalize materials which characterize the main features of the soil in the polar and boreal belts of Siberia,[4] based primarily on the personal investigations of the authors and on the material of regional soil-geographic summaries and individual scientific articles.

Analytical data will be given in the text only when unpublished material is cited; in all other cases references will be given to the corresponding sources in the literature.

Polar Belt

Limited studies have been conducted in recent years in the arctic and subarctic zones of the polar belt of Asia. Nevertheless, these investigations give new materials for the characterization of the peculiarities of processes of soil formation and confirm the necessity of differentiating the soils of the arctic and tundra zones. The soils of arctic regions often develop under aerobic conditions with a neutral or slightly alkaline reaction and the formation of a base-saturated humus horizon. Tundra soils are characterized by an acid reaction, and gleyization and ferruginization processes, even if they develop on solid rock (50).

Sod-arctic and bog-arctic soil groups, as well as arctic marshy solonchaks can be distinguished in the southern part of the arctic zone (34). The sod-arctic soils of the southern part of the zone are characterized by the absence of excessive wetting and gley processes; by a slightly acid, close to neutral, reaction; by a considerable content of humus with Ca fulvates and humates, and partly R_2O_3 fulvates and humates predominating in the composition of the organic substance; by a ratio between the C of humic acids and the C of fulvic acids of 0.6-0.9; by a high saturation of the adsorption complex, which has a somewhat low capacity; and by the accumulation of bases in the humus horizons and of mobile iron in the upper soil horizons.

Three facies can be distinguished in the Siberian tundra zone: 1) western (within the confines of the West Siberian lowland) — continental, 2) central — extracontinental, and 3) eastern — oceanic. Tundra soils have been studied in recent years in the western and central facies.

Three tundra subzones can be distinguished in the Western Siberian tundra when moving to the north (investigations in Yamala were conducted by Ivanova and Kosheleva).[5] These subzones are: the moss-shrub, moss-lichen, and moss-grass subzones with corresponding tundra gley podzolic soils, tundra gley soils, and tundra arctic soils, which in this case also show signs of gleization. The tundra gley podzolic soils are represented primarily by tundra illuvial, slightly humic, podzolic, and gleyed soils. They develop on coarse-textured materials, being frozen at a depth of 100-150 cm. They differ from the corresponding soils of the European North by a smaller humus content in the illuvial horizon and stronger gleization (apparently as a result of the closer permafrost). Signs of podzolization are found in their humus horizon in the form of individual light-colored lenses. Moreover, the humus horizon is characterized by the presence of rusty and cinnamon-brown spots. Its thickness varies from 5-10 cm and signs of gleyization are noticeable throughout the entire profile. The strongest reaction to gley with potassium ferrocyanide is observed in the A horizon, and a less strong reaction in the A_0 horizon and lower in the profile.

The tundra gley soils (of a fine texture) of the central subzone are not podzolized morphologically. Their gleyed horizon extends from the humus horizon (about 5 cm) to the permafrost (40-50 cm). They differ from the European type by the closeness of permafrost, by the high oxidation of the gley horizon, and by the presence of a supermafrost, gray gley horizon. It is possible that the latter corresponds to the so-called "suprapermafrost-retained humus" horizon (retention of the descending flow of humic substances in the suprapermafrost layer), characteristic for soils in the tundras of the Lena region.

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[3] The map was compiled by N. N. Rozov and edited by I. P. Gerasimov and Ye. N. Ivanova. Published by GUGK, 1960.

[4] The sub-boreal belt of Siberia and the Far East will be treated in a special paper.

[5] The mention of authors without a reference means that we used manuscript materials.

The soils of the northern subzone, those of the moss-grass tundras, are represented by humic-tundra arctic gley soils. They are developed under grass vegetation (cotton grass, sedge, grasses) with a height from 25-30 cm and a surface coverage of 30%-70%. The thickness of the A_0A_1 horizon reaches 3-10 cm. The absence of a gray suprapermafrost horizon is characteristic. The layer of blue gley reaches the permafrost layer.

Limited investigations were conducted at the southern boundary of the tundra in the vicinity of Salekhard by Ivanova and Kosheleva. They showed that the combination of elements of forest and tundra landscapes is characteristic of the forest-tundra of Western Siberia. Frost phenomena, such as a hillocky nano-microrelief and the appearance of soil thixotropy, develop in sparse forests. The soils (of a coarse texture) belong to podzolic illuvial, slightly humic gleyey soils. In the European forest-tundra the elements of sparse forests differ more clearly from the tundra elements, and the podzolic and illuvial-humic horizons are more pronounced in soils on coarse materials.

The soils of the central facies of the tundra zone of Siberia were studied in the lower reaches of the Lena River and on Lyakhovskiy Island by Karavayeva and Targul'yan. In the subzone of typical tundras were found tundra gley soils with permafrost at a depth of 40-50 cm. Their gley horizon extends some of the humus horizon to the permafrost. Thixotropic phenomena are absent. These soils differ from the tundra soils of Western Siberia by the high oxidation of the upper part of the gley horizon and by a thicker humus horizon. The soils have an acid and slightly acid reaction (pH of 5.0-6.0), a low degree of unsaturation (15%-20%), a slight differentiation of the profile by texture and total composition, and have a considerable amount of sesquioxides, soluble in the Tamm extract, especially iron. The distribution of available elements is apparently covered by the frost migration of solutions. Humus saturates the entire soil layer and accumulated in the suprapermafrost horizon.

Soils on coarse-textured, gravelly sandy loams and sands are characterized by the absence of excessive wetting, the predominance of aerobic processes, the absence of gleyization, and the presence of a thick humus horizon (from 15-20 cm) with about 6% humus containing accumulated exchangeable bases. The soils do not show signs of podzolization and gleization, are not thixotropic, and have no ice in them. Seasonal thawing reaches a depth of about 1 m. They have a slightly acid and acid reaction, a small unsaturation (10%-20%), a high clay content toward the surface, and an undifferentiated profile in total composition. The authors call them "no un-gleyed tundra soils." These soils differ from similar soils in Western Siberia by the Absence of gleyization, podzolization, and of illuvial-humic horizons with a deep penetration of humus along the profile.

The tundra-arctic soils of Lyakhovskiy Island develop under grass vegetation with grass up to 10 cm tall and are characterized by very slight gleyization. The humus horizon is shallow (1-5 cm) and corresponds to the horizon with the maximum (up to 80%) root content. The reaction is close to neutral, and the adsorption complex is saturated with bases. They are characterized by a considerable amount of humus on top (4%-7%) and its deep penetration into the profile. The accumulative hums horizon has a high adsorption capacity (20-30 meq) and is characterized by a considerable accumulation of exchangeable bases as compared to the parent material. According to total chemical and particle-size analysis there are signs of "podzolization" in the A horizon. The authors call these soils "slightly gleyey tundra-arctic soils," considering the predominantly fulvic acid nature of their humus (C of humic acids: C of fulvic acids is 0.3-0.5). According to all their other indications let us call them "slightly gleyey sod-tundra-arctic soils." They differ from the humic-tundra arctic gley soils of Yamal by the very weak development of gleyization and the presence of a humus horizon displaying the sod process. They are very similar to sod-arctic soils and are, apparently, intermediate to them, since they occur at the border of the zones.

The materials of recent investigations thus confirm that soils within the tundra zone of Asia are subgroups of a single group of tundra soils and there is no reason to distinguish the soils of the central extracontinental portion of the zone as a special genetic type, as is the case more to the south in the taiga-forest belt. This is evidently the result of the mildening influence of the Arctic Ocean on the climate of the northern shore of Asia.

Boreal Belt

The boreal belt occupies a tremendous area on the Eurasian continent. According to the investigations conducted in recent years (soil, climatic, geobotanical, etc.), there are three separate soil-bioclimatic regions in its Siberian and Far Eastern portion:

1) the Central Eurasian continental taiga-forest soils, which embraces the north of Western Europe and of the Russian Plain, a great part of the West Siberian lowland, and the southern part of Central Siberia. Its eastern boundary coincides with the limits of wide distribution of permafrost.

2) the East Siberian extracontinental permafrost-taiga zone with frozen-taiga soils, which includes the northern part of Central Siberia, the Eastern Sayan, the whole of Eastern Siberia, and is limited in the east by the Yablonovo and Stanovo watersheds.

3) The Far Eastern continental taiga-humid forest region with frozen-podzolic and forest-humic, mostly illuvial-humic soils.

The extensive (from west to east) Central Eurasian taiga-forest region is, evidently, very heterogeneous. It has a special facies of sod-yellow-podzolic soils in the extreme west, while in the east prolonged seasonal freezing has a tremendous effect on soil formation, as we will see later.

The Central Eurasian taiga-forest region in Siberia was studied primarily in its southern part, extending field soil investigation to the north in the Trans-Urals and the Yenisey region. The soil-geographic investigations of Ivanova, Zavalishin, Afans'yeva, Dvinskikh, Dolgova, Letkov, Lebedev, Petrov, Kachinskiy and Vadyunina, and others in the Trans-Urals had already shown that the soil-geographic zones and subzones of Northeastern Europe extend into the Trans-Urals. Here there are similar subzones of gley-podzolic, podzolic, sod-podzolic, and gray forest soils. The sod-podzolic and gray forest soils of the Trans-Urals are characterized by a more intensely pronounced sod process with an increase in their humus content.

Sod-podzolic gleyey soils with a second humus horizons in complexes and combinations with sod-gley soils are widely distributed in undrained plains in the southern taiga of the Uralian part of the West Siberian lowland. These soils have acquired here their own cartographic representation. We know from the literature that they are found up to the Yenisey River, at the boundary of the southern taiga and of the small-leaf forests (14, 22). Sod-podzolic soils have no second humus horizon, or a very faint one along rivers.

Sod-podzolic and gray forest soils have been studied in the southern regions of the West Siberian lowland primarily in the Omsk, Novosibirsk, and Tomsk Oblasts' in connection with large-scale soil surveys and soil studies in variety-testing areas. The materials have been generalized by Gorshenin (9, 10), Kuznetsov (3), Gradoboyev, Prudnikov, and Smetanin (11, 45) and lately by the members of the Biological Institute of the Siberian Branch, Academy of Sciences, USSR, which compiled a map of the Novosibirsk Oblast' under the supervision of R. V. Kovalev.

In spite of disagreements between their authors, these materials showed: 1) sod-podzolic soils with a second humus horizon, which have undergone the phase of meadow soil formation, are widely distributed in the southern taiga subzone; 2) the presence of signs of solodization in a number of sod-podzolic soils, which is expressed in the sharp differentiation of the horizons, the presence of free silicic acid, which is removed in the alkaline extract, and in the presence, in certain cases, of adsorbed sodium (9, 11); 3) the development of gray forest soils, differing from European forest soils by their lesser thickness and greater humus content, in drained relief as well as on high ridges in the subzone of small-leaf forests; and 4) the presence of peculiar gray solodized, often gleyey, forest soils, characteristic of the West Siberian lowland in undrained interfluves of the same subzone.

In addition to the foregoing subdivisions, certain investigators distinguish another transition belt between the southern taiga and the small-leaf forests, which they call the "subtaiga" belt. This belt is characterized by a combination of gray forest and sod-podzolic soils, often having a second humus horizon, as well as by the wide distribution of gray gleyey solodized forest soils, and meadows and lowland bogs in undrained interfluves. Being agriculturally climatic and agriculturally peculiar, this transition belt has not yet been characterized from the soil genetic point of view, since its characteristic soil subgroup has not been established yet.

Extensive studies of soils in the eastern part of Western Siberia and neighboring regions of Central Siberia have been conducted by the Krasnoyarsk Complex Expedition of the Council for the Study of the Productive Capacity of Russia of the Academy of Sciences of the USSR by Yerokhina, Budina, Gerasimov, Kirillov, Semina. These studies covered the southern taiga, the subzone of grass deciduous forests, and island steppes. It has been established (Veredchenko, 4) that the duration of seasonal soil freezing is of great importance for soil processes and soil properties. Freezing shortens the growing period and improves the water supply to plants during the dry spring-summer period. This ensures the development of early maturing varieties of agricultural crops and of thick, dense coarse grass in the forests. The root system of plants is near the surface, the humus horizons are shallow and have a high humus content, there are frost fissures at the soil surface, and gleyed horizons appear in the soils.

Sod-podzolic, long-seasonally-frozen, slightly gleyey soils predominate under drained conditions and sod-podzolic-gley soils under undrained conditions with more prolonged seasonal freezing in the southern taiga of the Yenisey section of the West Siberian lowland. The presence of a second humus layer is characteristic for both soils in the southern part of the subzone. The soils are characterized by a high humus content. The thickness of the humus horizon and the content of humus in it increase in soils under undrained conditions.

The gray forest soils also belong to long-seasonally-frozen, slightly gleyey soils under drained conditions and to long-frozen gray forest soils in undrained interfluves. Both soils are characterized by a high amount of humus, humus tongues (which are often found under cold and humic conditions), relatively weak unsaturation, and the impoverishment of the upper horizons in clay. Moreover, in both the subzone of deciduous forests as well as in the forest-steppe the soils have a second humus horizon, which is very constant in depth. This horizon is more pronounced in the more gleyed soils and disappears in the more podzolized soils.

The group of long-seasonally-frozen soils is a transition to the frozen-taiga soils of neighboring regions to the east, and, therefore, they are special subgroups of the corresponding soil groups. Their western boundary has not been established yet, because the central regions of the West Siberian lowland within the Novosibirsk and Tyumen Oblast's have not been sufficiently studied.[6] The contours of the northeastern

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boundary (being at the same time the boundary of the taiga-forest region) are being delimited within the limits of the Yenisey ridge on the basis of investigations by A. A. Yerokhina. These investigations showed that sod-podzolic long-seasonally-frozen soils are found at the foot of the southern part of the ridge under the light-coniferous grass-moss taiga. Higher on the slopes under the cover of the pine-fir moss-shrub taiga are found podzolized mountain taiga and mountain podzolic soils, which are very acid, saturated with humus tongues, and have prolonged seasonally or permanently frozen soil in the profile. Mountain tundra is found at a height of about 800 m.

Farther to the east the boundary between podzolic and frozen-taiga soils runs along the right (northern) bank of the Angara River and reaches the Lena River basin.

In the southern part of Central Siberia, deliminted by this boundary, studies were conducted by the East Siberian Branch, Academy of Sciences, USSR, and the University of Irkutsk (the results are generalized in the papers of Makeyev (32) and Nadezhdina (33)), the Krasnoyarsk expedition of the Council for the Study of the Productive Capacity Russia, the Academy of Sciences, USSR, and the members of the Dokuchayev Soil Institute, who visited the northernmost (Yerokhina and Nogina) and southernmost (Vishnevskaya and Targul'yan) regions of the area under study.

The materials obtained from all the foregoing studies bear witness to the rather complicated system of latitudinal zonality in this border area of the Eurasian taiga-forest region.

Sod-podzolic soils with a developed humus horizon, containing up to 5% humus, according to the data of Nogina, and having an acid (salt pH of 4-4.5), clay- and sesquioxide-impoverished pronounced podzolic horizon, are found in the north of the region under study in the southern taiga subzone. These soils are mixed with peculiar sod-taiga and sod-calcareous soils, developing on traps, their eluvium, and on various calcareous materials. The most complete description of the latter soils is given in the paper of Makeyev (32), who discusses the typical representatives of these soils and their transitions to sod-podzolic soils.

The amount of sod-calcareous soils increases toward the east, and the soil-formation process attenuates in this case as in others.

To the south of the described subzone there is a peculiar transition belt with mixed birch-pine forest, within which are found typical forest-steppe areas in the form of "islands".

The soil of this belt is complex and is represented, according to the data of B. V. Nadezhdina, by peculiar brown sod-forest soils, which are replaced at the transition of the forest-steppe islands by gray forest soils and then by chernozems.

Data on the gray forest soils of this region are available in a number of papers. They indicate that these soils are relatively shallow, but have a high humus content, especially at the surface. These soils are usually slightly podzolized and have a small exchange and hydrolytic acidity. Slight gleyization (mentioned earlier), associated with seasonal freezing, is characteristic only of gray forest soils of the more humid Yenisey region and attentuates toward the east in the direction of Irkutsk. In forest-free areas there is a pronounced progradation of the humus horizons (Makeyev, 32).

The nature of the sod-forest brown soils, distinguished by Nadezhdin (35), remains obscure as yet. We believe that it is more correct to consider them as taiga sod soils and that not too much importance should be given to variations in clay content along the profile, which, according to the observations of Nogina, are found in various soils of the Cis-Baikal region at various depths and are attributable to the heterogeneity of the soil-forming parent material. Thus, the term "brown" in this case can only have the meaning of color and should not be associated with soils of brown earths of oceanic regions, which differ so much from them according to hydrothermal conditions.

Farther to the south, in the piedmont areas of the Sayan, the belt with mixed forests with forest-steppe islands is again replaced by forests of the southern taiga type with sod-podzolic and then podzolic seasonally-frozen soils. According to the data of Makeyev, among the latter are found podzolic residually-solodized soils with a very sharply differentiated soil profile with "amorphous" silicic acid and a small amount of adsorbed sodium.

The vertical series of soils of Eastern Sayan was studied by Vishnevskaya and Targul'yan, who traveled from Nizhneudinsk to the summit of the watershed range. At the bottom there is a belt of fir-cedar moss-shrub taiga on frozen-podzolic humic soils with greatly developed permafrost as a result of the smoothness of the relief and the intense weathering of rocks. Farther there is a belt of cedar-deciduous moss taiga with podzolic illuvial-humic soils, within humus-podzolic soils under a more depressed forest and humus-peat frozen soils.

As a result of all the listed investigations in Western Siberia and the south of Central Siberia, extensive material has been collected which supplements the generalizing reports of Gorshenin (9, 10), and Nikolayev (38). This material shows firstly that in spite of geomorphological and lithological differences between the West Siberian lowland and the Central Siberian plateau and the Yenisey ridge, adjoining the lowland from the east, the soil in all these regions has common features expressed in the general development or predominance of podzolic soils, and, secondly, that in the Siberian part of the Central Eurasian soil-bioclimatic region there are two distinct

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[6] At the present time soil studies are being conducted by the V. V. Dokuchayev Soil Institute and the Siberian Branch, Academy of Sciences, USSR in these regions in relation to the compilation of the sheets of the State Soil Map of the USSR (R. V. Kovalev, and K. A. Ufintseva).

soil-bioclimatic facies: 1) with normal seasonal soil freezing in winter, and 2) with prolonged seasonal winter-spring-summer soil freezing. Because of the great importance of prolonged seasonal freezing for the genesis of soils and their fertility, the thermal regime of soils and its role in soil formation and plant nutrition must be studied more comprehensively.

The division of the southern taiga in the West Siberian lowland into provinces, as outlined by Gorshenin (10), is also probably related to this phenomenon.

The East Siberian extracontinental region of frozen-taiga soils, which includes the Yano-Indigirka region (the coldest area of the Northern Hemisphere, which contains the cold pole) is located to the east of the Central Eurasian continental region of podzolic and gray forest soils. More than half of the surface of this area is occupied by large mountains with plateaus and lowlands in-between. The largest intermontane region is the Central Yakutian depression, whose peculiar soil has a long history of study (1, 29, 7, 18, 19, 15, 16).

In recent years the distribution of froze-taiga soils has been established on the basis of the foregoing investigations and new materials.[7] These soils are now considered in classification schemes as an independent soil group, including "pale-yellow sod-forest soils" (according to Zol'nikov).

According to modern views, frozen-taiga soils form under light-coniferous forests in the presence of permafrost (or very prolonged seasonal freezing) in the soil profile, which creates conditions for a non-leaching or semi-leaching water regime and the formation of a temporary suprapermafrost water table. These soils are characterized by the weak differentiation of their profile: the accumulation of light-colored humus, saturating the soil in its upper part; the presence of dynamic frost action in the soil mass, which leads to the displacement and partial mixing of the horizons, and the formation of microrelief and a spotty soil complexity; and the upward migration of soil solutions as a result of frost action (and sometimes in summer). The area occupied by frozen-taiga soils is considerable. It includes at least three bioclimatic subgroups: 1) gleyey-frozen-taiga soils of the northern light-coniferous taiga with "climatic" surface gleyization (associated with low evaporation), with a very acid reaction, with a high content of available iron compounds in the upper horizons, and intense dynamic frost action in the soil mass; 2) frozen-taiga soils of the central light-coniferous taiga in the western part of the frozen-taiga region, which develop under conditions where precipitation exceeds evaporation, characterized by an acid reaction and signs of weak podzolization, or the absence of podzolization and the presence of suprapermafrost gleyization; 3) frozen-taiga pale-yellow soils of the central light-coniferous taiga of Yakutiya, which develop in areas where evaporation predominates over precipitation. These latter soils are characterized by a pale-yellow coloration, possibly due to films of iron on the soil particles (?); a neutral reaction; the upward migration of solutions from the suprapermafrost layer to the surface; and the occasional presence in the composition of the adsorption complex of small amounts of exchangeable sodium, which is expressed in the weak solodization of the soils. Among these, frozen-taiga pale-yellow solodized soils are distinguished as a special species of soil. These soils have been recently studied in detail by Zol'nikov (18). In combination with these there are frozen solonetzes and special meadow-chernozem-like frozen soils.

The mountain structure are rather evenly distribution in the territory of the extensive East Siberian frozen-taiga zone and are characterized by a number of peculiarities in the structure of the vertical distribution of soils, which is of the same type, but includes a number of latitudinal-zonal and facies variations. The mountains can be divided into the northern, central, and southern groups according to the structure of vertical soil distribution. Central extracontinental and more moist eastern and western soil varieties can be distinguished within each mountain group.

Soil investigations in the northern group of mountains within the Verkhoyansk range and the Cherskiy range have been conducted by Academicians Gerasimov and Vas'kovskiy (2, 3), who established the main physiographic peculiarities and the main features of soil in these regions. Vasil'kovskiy calls the predominant mountain soils "frozen earths" and notes the appearance of peculiar mountain taiga-steppe soils on southern warmed slopes.

A number of investigators crossed these ridges from the city of Khandyg to the city of Magadan (Zol'nikov, Ivanova, Rozov, and Naumov, 1958-1959). Their studies showed that the mountain structures to the west of the Yablonov range are characterized by mountain gleyey-frozen-taiga soils under sparse deciduous forests. Complexes of frozen tundra soils are found in passes. Shrub valley tundras, descending very low, are found along intermontane valleys in the sparse forest belt. Peculiar mountain frozen-taiga-steppe soils under grass-mixed-herbage vegetation with xerophytes at the base of the grass stand are widespread in the sparse forest on stepp, southern slopes. These soils have an almost neutral reaction, are base saturated, and their upper horizon is slightly humic and underlain by a humus horizon (the total thickness of these horizons varies from 10-15 cm). Carbonate films sometimes appear on the gravel below and the reaction becomes weakly alkaline. Well-developed larches are sometimes found on these soils among the grass. They occur singly or in the form of clusters.

The soil of the central and southern mountain groups of Eastern Siberia has been studied by a number of complex expeditions of the Council for the Study of the Productive capacity of Russia, Academy of Sciences USSR (with the participation of the V. V. Dokuchayev Soil Institute); the Tuva expedition (1952-1957), the Buryat expedition (1953-1956), the Southern Yakutiya expedition (1953-1954, 1959-1960), and also by the Chita soil expedition of the Soil Institute in 1957.

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[7] Investigations by V. G. Zol'nikov, L. G. Yelovskaya, and others in Central and Northern Yakutia; by Ye. N. Ivanova in the lower reaches of the Lena River; by V. G. Zol'nikov, Ye. N. Ivanova, and N. N. Rozov at the foot of the Verkhoyansk ridge.

The Tuva Autonomous Region, studied by Nosin in collaboration with Yurlova, Vishnevskaya, Letkov, and Naumov, is located between the southern and eastern slopes of the Altay-Sayan mountain structure. As a result of the foregoing investigation it has been established that the northeastern part of Tuva belongs to the frozen-taiga region of the boreal belt, whereas the southwestern part, which is of a transitory nature, belongs to the sub-boreal belt. There are essential differences in the structure of the vertical zonality of soils between these parts.

The northeastern part of the Tuva Autonomous Region is characterized by the following vertical series of soils, beginning from the bottom: 1) mountain-taiga long-seasonally-frozen sod soils, 2) mountain-taiga slightly podzolized acid soils, also long-seasonally-frozen, and 3) mountain-tundra soils. Within the taiga-forest vertical belt in the southwest we have the following sequence (also from bottom to top): 1) mountain gray forest soils, 2) mountain-taiga sod soils, 3) mountain-taiga humic long-seasonally-frozen soils, and 4) mountain-meadow and mountain-tundra soils.

Mountain-taiga sod soils develop on the products of weathering of various rocks. Coarse and medium clay loams predominate. Clay usually accumulates in the upper part of the profile and is more rarely evenly distributed along the profile. The pH of these soils is 5-6, their exchangeable hydrogen content is about 1%, and they are base saturated. The humus horizon is up to 10-15 cm thick and contains 6%-9% humus. Humus penetrates to a depth of 30-40 cm (about 1%-2%).

As mentioned earlier, mountain-taiga long-seasonally-frozen acid soils develop in the central and upper parts of the taiga belt, primarily in the northeast. They are characterized by a very acid reaction (pH of 2-3), a high content of exchangeable hydrogen (5-10 meq), strongly unsaturated (80%), a shallow humus horizon (less than 10 cm), and a high content of slightly decomposed humus (4%-16%) with shallow penetration along the profile. The parent material consists of coarse gravelly clay loams whose clay content increases toward the surface. The soils are slightly podzolized at the surface (to a depth of 6-8 cm). Humus-peat gleyey-frozen-taiga soils with permafrost are found on northern slopes under sparse forests with a shrub-moss cover. Sod-podzolic soils, developing on more level relief features, are found at the lower boundary of the mountain-taiga acid soils at the transition to mountain-taiga sod soils.

Mountain-taiga humus soils (slightly acid and not podzolized) occupy the upper part of the taiga belt in the southwest. They develop under grass-shrub-moss cedar-larch taiga and are distinguished by prolonged seasonal freezing. They are characterized by a humus horizon 8-12 cm thick (with 13%-18% humus). They form on coarse and medium gravelly clay loams. Clay is relatively evenly distributed along the profile, or is at a maximum at the surface. The reaction of these soils is moderately acid (pH of about 4) and their unsaturation is medium (25%-40%). The soils are not podzolized, or very weakly podzolized.

Studies in the mountain taiga of the Trans-Baikal region and its western, most continental part, were conducted by N. A. Nogina (39, 40), K. A. Ufimtseva, K. P. Bogatyrev, and N. A. Karavayeva. Nogina distinguishes a belt of mountain-tundra soils (above 2000 m), a belt of mountain forest-tundra (1700-2000 m) with mountain-taiga, ferruginized surface-gleyed soils; an upper taiga belt (1400-1700 m) with dwarfed larches (with alders, decumbent cedar, a shrub cover, and single kurtiki moss) on mountain-taiga surface-ferruginized soils; and a belt of central taiga (below 1300 m), larch taiga with a grass-shrub cover on mountain-taiga podzolized soils (mountain taiga ferruginized podzolized soils, according to Nogina).

Mountain-taiga ferruginized surface soils are most characteristic of this region. They develop under conditions of pronounced frost phenomena (hillocky microrelief, frost-shattered gravel, etc.). The profile is clearly differentiated: under the litter there is a brownish-nutty horizon which gradually becomes browner and merges with the parent material. The soils develop on the gravelly eluvium of solid rocks of a sandy-coarse clay loam with almost evenly-distributed clay along the profile. They are slightly saturated with humus to a shallow depth, have an acid reaction (pH 4), a high content of hydrogen (4 meq under the litter), which penetrates deeply into the profile (1 meq at 65 cm), and an unsaturation up to 70% in the humus horizon and up to 45% in the sub-humus horizon. Total chemical analysis indicates that sequioxides accumulate immediately under the litter, they are more rarely evenly distributed along the profile. This fact is interpreted by Nogina as the result of their upward migration under the action of frost.

Bog-frozen-taiga peat-gley soils and frozen bog soils occur in combination with the soils just described.

In the central part of the taiga belt there are podzolized (ferruginized) mountain-taiga soils. They are acid, slightly podzolized (pH 4), have a medium unsaturation (55%) and shallow humus and penetration of exchangeable hydrogen (to a depth of 35 cm). These soils contain permafrost when they develop on fine earth materials. All the semi-hydromorphic and hydromorphic soils of the taiga belt also contain a frozen layer.

Mountain-taiga sod soils, free of a frozen layer, develop in the form of a special zone in the south in the lower part of the taiga belt.

In the eastern part of the Trans-Baikal region, to the east of the Vitim River (investigated by Sokolova and Sokolov), there is a transition to moister regions and the podzolic process intensifies in the soils. Three subzones are distinguished in the taiga belt of the Eastern Trans-Baikal region: the upper, central, and lower taiga.

In the upper taiga subzone (from 1000-1200 to 1300-1600 m elevation) the authors distinguish mountain taiga-frozen peat soils on more weathered materials and mountain podzolic illuvial-humic-ferruginous soils on shallow gravel deposits. "Pre-podzolic soils" occupy a small area. In the opinion of the authors, they represent the first stages of development of the podzolic process on solid rocks, whick actually does not show any signs of it yet.

Mountain podzolic illuvial-humic-ferruginous soils are very similar to acid podzolized soils in the upper eastern Tuva taiga. They are very acid (pH of 2-3), have a whitish A_2 horizon which is strongly and deeply saturated with humus (humus saturated).[8] The amount of humus in the A_2 horizon is 6%-9% and at a depth of 50 cm it is 1.5%-3%. There are profiles with an additional illuvial-humus horizon (saturated-illuvial-humus). In conformity with the humus profile, the exchangeable hydrogen in the A_2 horizon reaches 10-13 meq and at a depth of 40-50 cm, 1-5 meq. Unsaturation is 80%-90% in the A_2 horizon and 40%-50% in the lower part of the profile. According to total chemical analysis the soils are moderately podzolic. The parent materials are coarse and medium clay loams; the clay content is somewhat low in surface, i. e., with the same acidity as in the Tuva soils of the eastern Trans-Baikal region, they are more strongly podzolized and have a morphologically expressed whitish horizon. Therefore, they can be considered as humus-saturated mountain podzolic soils.

"Pre-podzolic" soils are somewhat similar to the mountain-taiga surface-ferruginized soils described by Nogina, but they develop on very fresh eluvium. The content of clay and particles <0.01 mm in diameter in these soils continuously increases toward the surface, reaching a maximum in the upper ferruginized horizon (in the mountain-taiga surface-ferruginized soils these fractions are either stable, or decrease in the upper horizons). According to total chemical analysis, both the soils being compared have a maximum of Al_2O_3 and Fe_2O_3 immediately under the litter, but the surface-ferruginized soil has a weak eluvial horizon under the ferruginized horizon (this is the reason why Nogina assumes the possible upward migration of solutions). Both soils are acid and not strongly saturated with humus. Thus, in spite of the morphological similarity of the soils under discussion, they differ somewhat in their chemistry and in the intensity of frost action phenomena.

Frozen-taiga peat-humic-gleyey soils on more fine-textured materials and mountain-podzolic soils on more coarse-textured material develop in the central taiga subzone at elevations from 900-1100 m. Mountain-podzolic soils are developed on more weathered material. The clay content usually decreases toward the surface, or is evenly distributed along the profile. The soils are slightly, but deeply saturated with humus and have an acid reaction (pH of 3). The content of adsorbed hydrogen is moderate (6-8 meq in the A_2 horizon and 1-3 meq in the BC horizon at a depth of 30-40 cm), and unsaturation is 50%-80%. According to total chemical analysis these soils can be considered as moderately podzolic.

Farther to the east, within the Stanov and Tukuringra ranges, the soils were studied by Gerasimov with the partial collaboration of Ivanova and Rozov. Mountain frozen-taiga soils, which are podzolized in places, and mountain frozen-taiga, humus-calcareous soils are found on the northern slopes of the Stanov range in the Aldan highland, which descends to the Central Yakutian depression. Mountain frozen-taiga soils are weakly saturated with humus, and are very acid (pH of 2-3). Their unsaturation is about 90% (exchangeable hydrogen from 15-20 meq) and they are usually slightly podzolized.

The mountain frozen-taiga humus-calcareous soils are shallow. They are characterized by a high content of humus in the A_0A_1 horizon (12%-20%) and its rapid decrease in the A_1 horizon (2%-4%). The total thickness of the foregoing horizons is about 20 cm.

The southern slope, facing the Amur River and having a more humid climate, is characterized by the following structure of vertical soil zonality (from top to bottom): 1) mountain-tundra zone with mountain-tundra peat soils and with large areas under rock streams; 2) a belt of decumbent vegetation and sparse forests with mountain frozen-taiga saturated-illuvial-humus soils, bog-frozen-taiga soils, and frozen bog soils; 3) central mountain taiga subzone where mountain frozen-podzolic soils, mountain bog-frozen-podzolic soils, and frozen bog soils predominate; and 4) the lower mountain taiga subzone with mountain-taiga sod soils and mountain sod-podzolic, deeply frozen soils in combination with frozen hydromorphic soils.

The mountain frozen-taiga saturated-illuvial-humus soils are very acid (pH of 3), they contain a large amount of exchangeable hydrogen (8-12 meq) in the A_2 horizon, and are 80%-90% unsaturated. Generally, humus penetrates deeply into the soil and forms an illuvial horizon. The soils form on gravelly coarse clay loams. They have the maximum amount of clay at the surface and are slightly or moderately podzolized.

Mountain frozen-podzolic soils are not saturated with humus, contain little exchangeable hydrogen (4-6 meq), are acid (pH of 3), and are strongly unsaturated since they develop on sandy loam granite eluvium. In the higher parts of the belt the soils are mountain-podzolic illuvial-humus soils, while in the lower parts they are mountain-podzolic soils.

Mountain-taiga long-seasonally-frozen sod soils (frozen-gleyey) are characterized by a thick but very acid humus horizon with a considerable accumulation of cations (from 0.9 meq in the A_2 horizon to 3.3 meq in the A_1 horizon), but primarily hydrogen. The reaction is acid (pH of 3) throughout the profile and there is a large amount of exchangeable hydrogen in the entire profile (8-11 meq in the A_1 horizon and 5-3 meq at a depth of 50-70 cm in the frozen-gley horizon). These soils develop on fine clay loams, which are slightly stony in the upper part of the profile. Hydromorphic frozen soils occur in combination with the foregoing soils.

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[8] The term "humus-saturated" defines soils which have a humus-tongue horizon with decreasing humus content immediately below the accumulative-humus horizon.

Investigations in the mountains of the East Siberian frozen-taiga region made it possible to distinguish a number of peculiarities of the main groups of mountain soils and to establish patterns in their geographical distribution, in spite of certain controversial problems.

The mountain-tundra soils of Eastern Siberia, as compared to the mountain-tundra soils of the neighboring regions, such as Central Eurasia and the Far East, are characterized by a greater degree of dryness, lesser thickness, and the very weak development of gleyization. In the most continental parts of the region these soils form under a cover of xerophytic vegetation where lichens predominate and there is little or no moss. Certain investigators suggest that they be considered as a special soil group -- "bald mountain sod" soils (24). The appearance of these soils is associated, on the one hand, with the increasing dryness of the climate (Trans-Baikal) and, on the other hand, with the increasing duration and severity of winters, also accompanied by dryness (upper mountain belt of the Verkhoyansk and Cherskiy ranges).

Mountain frozen-taiga soils, including also mountain-taiga long-seasonally-frozen soils, are the most widespread and at the same time the most characteristic soil groups within the East Siberian frozen-taiga region. They vary considerably in their properties when going from north to south and from west to east, apparently forming a series of bioclimatic subgroups. The material available at the present time makes it possible to examine the problems of the presence of permafrost in them, the distribution and form of frost phenomena, and the distribution of podzolization.

Permafrost is, apparently, found everywhere in the profile of mountain frozen-taiga soils in Northern East Siberia. Permafrost can be absent in the soils of the taiga belt, located in the most xerophytic conditions in the central group of mountains (upper part of slopes, and on coarse gravelly material), but seasonal freezing is prolonged.

The foregoing extensive observations made in the mountains of southern East Siberia give the following picture. Taiga soils, developed on gravelly material under both xeromorphic conditions as well as on gentle slopes can be permanently and seasonally frozen. Frozen soil appears in them and intensifies at the transition to more humid provinces, or as rocks weather and form finer earth products. As weathering intensifies and relief features become more gentle, frozen soil may appear in the lower mountain belts, usually on northern slopes, while it is absent in the upper belt. Frozen mountain-taiga soils are more widespread toward the east, probably as a result of increasing moisture. In the southwestern part of the frozen-taiga region the soils are not frozen, in the eastern Trans-Baikal region frozen soil is found on finer earth materials, while on the slopes of the Stanov and Tukuringr ranges it is found in gravelly and friable soils. Taiga soils with signs of hydromorphism always contain permafrost.

All the frozen-taiga soils discussed show the effect of frost action on soil formation, whether they contain permafrost or long-seasonally frozen layers or not. This effect is expressed in the formation of a highly ferruginized soil eluvium on which soils form with a special composition of their organic substance and with highly mobile humus, which gradually saturates a considerable thickness (humus-saturated soils).

Soils with the most sharply expressed frost action phenomena (mountain surface-ferruginized soils) are found under the most severe conditions in the upper taiga of the western Trans-Baikal region and of the Verkhoyansk range. Soil formation conditions become milder to the east and west and the process of iron migration to the soil surface under the action of frost attenuates.

The reaction of frozen-taiga soils is very acid, as a rule, but there is usually no podzolization, or it is very weak. In the mountains to the north of the East Siberian region we find slightly podzolized frozen-taiga soils only in its more humid peripheral part on the warmest southern slopes (Kolyma River basin). Under the same relief conditions in continental areas (Indigirka River basin) we find the peculiar mountain frozen-taiga-steppe soils, described earlier. We still have little data on the distribution of podzolization in the mountain frozen-taiga soils of the Central part of the region.

This process was noted in the northern areas of the Yenisey range in the west, on the northern slope of the Stanov range in the east, and was almost absent in the central area in the Northern Trans-Baikal.

Mountain podzolized frozen-taiga soils are found much more often in the south of the East Siberian region. They develop primarily in its southwestern and, especially, southeastern parts, but are also encountered sporadically in the more continental central areas. These soils are very acid in all cases, but podzolization is weaker in the west and much more pronounced in the east (in the region of the Stanov and Turkuringr ranges), where these soils are gradually replaced by mountain frozen-podzolic soils, which are mostly illuvial-humic.

The investigations of Nosin, Nogina, Ufimtseva, and Gerasimov show that in the lower parts of mountain slopes (in the southern regions of East Siberia) mountain frozen-taiga soils are replaced by peculiar mountain-taiga sod soils, which form under grass larch forests. These soils, which form the lower mountain soil zone, do not contain permafrost in their profile. Their seasonal freezing is not prolonged, their humus is slightly mobile, frost action phenomena are weakly developed and express themselves only in a certain ferruginization of the soil eluvium, their reaction is less acid than in frozen-taiga soils, and they are drier and much warmer. All the listed features of mountain-taiga sod soils, as well as their position in the series of vertical zonality make them an independent soil group, differing from frozen-taiga soils. Mountain sod-taiga soils are weakly podzolized and only in the western and extreme eastern parts of their distribution area.

All the foregoing materials point to the specificity of the soil in the East Siberian frozen-taiga region, which exhibits a number of new processes and forms of soil formation. We hope that further investigations will uncover a number of peculiarities in the biological cycle, and thermal and water regime of the soils. This will be of great importance to the development of agriculture and forestry in this coldest region of the boreal belt.

BIBLIOGRAPHY

1. ABOLIN, R. I. 1929. Geobotanical and soil description of the Lena-Vilyus valley. Izd. Akad. Nauk SSSR.

2. VAS'KOVSKIY, A. P. 1959. Geography and genesis of forest soils in the Far North-eastern USSR. Kolyma, No. 1.

3. VAS'KOVSKIY, A. P. 1960. Geographical characteristics of the forest region in the Far Northeastern USSR. Krayevedch. zap. No. 3. Magadan.

4. VEREDCHENKO, YU. P. 1960. Agricultural characterization of soils in the Krasnoyarsk agricultural region. Dissertation. Pochv. in-t im. V. V. Dokuchayeva. Moscow.

5. GERASIMOV, I. P. 1933. Soil-climatic facies of the plains of the USSR and neighboring countries. Tr. Pochv. in-ta im. V. V. Dokuchayeva, 8 (5).

6. GERASIMOV, I. P. and N. N. ROZOV. 1940. Main problems of the geography of West Siberian soils. Probl. sov. pochvov. Sb. 11.

7. GERASIMOV, I. P. 1952. Present outlook for postglacial phenomena in the vicinity of the coldest region of the world. Izv. Akad. Nauk SSSR. No. 5.

8. GLINKA, K. D. 1927. Soils of Yakutia. Collection of articles. Izd. Akad. Nauk SSSR.

9. GORSHENIN, K. P. 1955. Soils of Southern Siberia (from the Urals to Lake Baikal). Izd. Akad. Nauk SSSR.

10. GORSHENIN, K. P. 1957. Provincial characteristics of the major soils of the southern Siberian taiga. In the collection: Problems of the genesis and geography of soils. Izd. Akad. Nauk SSSR.

11. GRADOBOYEV, N. D., V. M. PRUDNIKOVA and N. S. SMETANIN. 1960. Soils of Omsk Oblast'. Omsk. kn. izd.

12. GRIGOR'YEV, A. A. 1926. Geology, relief, and soils of the southwestern part of the Lena-Aldan plateau and the Verkhoyansk ridge. In the book: Materials on the complex study of the Yakutian ASSR. No. 4. Izd. Akad. Nauk SSSR.

13. GIRGOR'YEV, A. A. 1956. Subarctic. Geografiz., Moscow.

14. DRANITSIN, D. 1914. Secondary podzols and the displacement of the podzolic zone in the northern Ob'-Irtysh watershed. Izv. Dokuchayevsk. pochv. komis. Vol. 2. St. Petersburg.

15. YELOVSKAYA, L. G. 1959. Brief characterization of soils in the Irelekh River basin and possibilities for their agricultural reclamation. Izv. Akad. Nauk SSSR. No. 4.

16. YELOVSKAYA, I. G. 1959. Certain data on the soils of the Malaya Botuobi River basin. Nauchn. soobshch. Yakutsk. fil. SO Akad. Nauk SSSR. No. 2.

17. ZAVALISHIN, A. A. 1944. Problem of soil formation in the central taiga of the Trans-Urals region. Pochvovedeniye. No. 4-5.

18. ZOL'NIKOV, V. G. 1954. Soils of the eastern part of Central Yakutia and their utilization. Materialy o prirodn. uslov i s.-kh. Tsentr. Yakutii. No. 1. Moscow.

19. ZOL'NIKOV, V. G. 1957. Soils of the Lena and Olekmin regions of Yakutia and prospects for their agricultural utilization. Materialy o prirodn. uslov. i s.-kh. yugo-zapada Yakutii. No. 2, Moscow.

20. IVANOVA, YE. N. 1943. Soil investigations in the northern European USSR. Pochvovedeniye. No. 4-5.

21. IVANOVA, YE. N. and N. N. ROZOV. 1960. Work conducted on the general cartography of Siberian soils and its relation to geobotanical investigations. Summaries of papers presented at the Conference on Problems of the Cartography of Vegetation (Novosibirsk, November 1960). Izd. Akad. Nauk SSSR.

22. IL'IN, R. S. 1930. Nature of the Naryn region. Relief, geology, landscapes and soils. In the book: Materials for the study of Siberia. Vol. 2. (Tomsk, otd. o-va izuch. Sibiri i yeye proizvodit. sil). Tomsk.

23. KALASHNIKOV, K. V. 1960. Podzolic soils of the Khanty-Mansi National Okrug and the influence of cultivation on their properties. Dissertation. Mosk. s.-kh. akad. im. K. A. Timiryazeva.

24. KARAVAYEVA, N. A. 1958. High-mountain soils of Eastern Sayan. Pochvovedeniye. No. 4.

25. KARNAUKHOV, N. I. 1959. Characterization of soils in the spruce forests of the Central Angara region in the Ust'-Udinsk rayon of Irkutsk Oblast'. Izv. Sib. otd. Akad. Nauk SSSR. No. 8.

26. KACHINSKIY, N. A. and A. F. VADYUNINA.

1950. Experimental agricultural-physical characterization of soils, taking the Central Urals as an example. Moscow-Leningrad.

27. KIRILOV, M. V., A. I. KRAVCHENKO, V. YE. PENZOVA, and YE. N. SHTEYN. 1952. Brief characterization of the major soil groups of the flood zone of the Krasnoyarsk Hydroelectric Power Station. Uch. zap. Krasnoyarsk. ped. in-ta. Vol. 10.

28. KONOVALENKO, V. G. 1958. New data for the general characterization of the flood-plain lands of the Khanty-Mansi National Okrug. Tr. In-ta Kraynego Severa. Vol. 6.

29. KRASYUK, A. A. 1927. Soils of the Lena-Amga watershed. Izd. Akad. Nauk SSSR.

30. KUZNETSOV, K. A. 1949. Soils of the southeastern part of the West Siberian plain. Tr. Tomsk. un-ta. Vol. 106.

31. LEBEDEV, B. A. 1956. Soils of the non-chernozem belt of the Urals. Tr. In-ta biol. Ural'sk. Fil. Akad. Nauk SSSR. No. 7.

32. MAKEYEV, O. V. 1959. Sod taiga soils in the south of Central Siberia (genesis, properties, and methods of rational utilization). Buryatsk. kn. izd. Ulan-Ude.

33. MARKOV, M. V. 1959. Characteristics of soil formation depending on relief in the Khanty-Mansi National Okrug. Dokl. TSKhA (Mosk. s.-kh. akad.). No. 47.

34. MIKHAYLOV, I. S. 1960. Certain characteristics of sod arctic soils on Bol'shevik Island. Pochvovedeniye, No. 6.

35. NADEZHDIN, B. V. 1960. The Lena-Angara forest-steppe (soil-geographical outline). Izd. Sib. otd. Akad. Nauk SSSR.

36. NEPRYAKHIN, YE. M. 1958. Sod-podzolic soils in the south of Tomsk Oblast'. Uch. zap. Tomsk. un-ta. No. 34.

37. NEPRYAKHIN, YE. M. 1960. Gray podzolized forest soils in the south and southeast of Tomsk Oblast'. Uch. zap. Tomsk. un-ta. No. 36.

38. NIKOLAYEV, I. V. 1948. Soils of Irkutsk Oblast'. OGIZ, Irkutsk.

39. NOGINA, N. A. 1956. Mountain-taiga ferruginized soils in East Siberian regions. Proceedings of the VI International Congress of Soil Science, V Commission. Izd. Akad. Nauk SSSR.

40. NOGINA, N. A. 1957. Soil of the Vitim Plateau. In the bock: Problems of the genesis and geography of soils. Izd. Akad. Nauk SSSR.

41. NOSIN, V. A. 1957. Soil of the Tuva Autonomous Region. Tr. Tuvinsk. kompleksn. eksp. No. 3. Izd. Akad. Nauk SSSR.

42. PETROV, B. F. 1952. Soils of the Altay-Sayan region. Tr. Pochv. in-ta Akad. Nauk SSSR. Vol. 35.

43. POPOV, L. V. 1960. Soils of the northwestern part of Bratsk rayon. Tr. Vost.-Sib. fil. (Sib. otd. Akad. Nauk SSSR), No. 22.

44. Soil-geographical investigations in the Urals. 1954. Tr. Poch. in-ta im. V. V. Dokuchayeva. Vol. 43.

45. PRUDNIKOVA, V. M. 1961. Sod-podzolic soils of the southern taiga of the Omsk Oblast' and certain methods of increasing their fertility. Dissertation. Permsk. s.-kh. in-t. Omsk.

46. RODE, T. A. and I. A. SOKOLOV. 1960. Characterization of mountain-tundra landscapes of the Trans-Baikal region. Pochvovedeniye. No. 4.

47. SEMINA, YE. V. 1961. Gray forest soils of the Krasnoyarsk forest-steppe and certain problems of their genesis. Pochvovedeniye. No. 1.

48. SOKOLOV, I. A. 1958. Soils of the meadow steppes of the Eastern Trans-Baikal region. Pochvovedeniye, No. 11.

49. SUMGIN, M. I. 1931. Soil formation conditions in permafrost regions Pochvovedeniye, No. 3.

50. TARGUL'YAN, V. O. 1959. First states of weathering and soil formation on extrusive rocks in the tundra and taiga zones. Pochvovedeniye No. 11.

51. TETERINA, L. V. and YE. I. CHERNYAK. 1958. Soils of the basin in the lower reaches of the Yakotit River. In: Materials on soil and agricultural-chemical investigations in Yakutia. Moscow. Tr. In-ta biol. Yakutsk. fil. So Akad. Nauk SSSR. No. 5.

52. TYRTIKOV, A. N. 1957. Thermal regime of soils in various plant communities in the Igarka region. Pochvovedeniye, No. 6.

PROBLEM OF THE BOUNDARY BETWEEN LATITUDINAL SOIL ZONES AND VERTICAL SOIL BELTS IN CENTRAL ASIA

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The general principles of the study of mountain soils were established by V. V. Dokuchayev; he formulated the law of the vertical zonality of soils. Since then extensive material has been accumulated on the soils of mountain countries, which characterizes their properties, conditions of soil formation, and peculiarities of distribution. The idea of Krasnov (12) that soils change with increasing absolute elevation has grown now into a whole system of knowledge. It has been established that the structure of altitudinal soil zonality obeys the general law of zonality in nature. This is expressed in the unduplicated characteristics of soils in each mountain country, associated with the zonal position of the latter. We also know that both the structure and genetic characteristics of individual soils reflect the position of a given mountain country with respect to the ocean, i. e., its contentality. Thus, another important soil-geographical regularity, i. e., the provinciality of soils, is also reflected in the soil appearance of mountain countries.

Nevertheless, the study of mountain soils remains a little developed part of soil geography. Especially neglected are such important problems as the boundary between the region of latitudinal soil zonality and the region of vertical belts.

In the proposed list of symbols for the State Soil Map of the USSR and certain of its published Central Asian sheets, soils are divided vertically only according to orographic features, without taking into consideration the whole combination of natural conditions and genetic characteristics of soil formation in the mountains. As a result of such an approach, only dark sierozems are distinguished as mountain soils, while typical and light sierozems, together with gray-brown, takyr, and other soils of the latitudinal desert zone are grouped together as plain soils.

In analyzing the structure of the vertical soil belts of the Turan type, Fridland (29) begins the system of soil belts of the Eastern Tian-Shan, Pamirs-Altay, and Kopetdag with typical sierozems.

Rozanov (24) has a more correct view of this problem, based on his personal observations and the generalization of the extensive material collected at Central Asian soil institutes. When describing the desert steppes of piedmont plains and foothills with light, typical, and dark sierozems, he writes that "here the law of vertical zonality is reflected in the nature of the soil" (p. 227). Unfortunately, contradictions in his paper deprives the clarity of differentiation of regions with vertical and latitudinal zonality. Thus, several pages earlier he considers the "desert, or extra-arid, belt" as part of the "vertical soil-vegetation belts" of Central Asia (p. 213).

The region of sierozem development is a system of genetically interrelated geomorphological elements. These are most often series of variously aged terraces of one and the same river, or a system of steps, "piedmont steps", of which the lower, youngest steps, are occupied by light sierozems, which are replaced successively with elevation and step age by typical and then dark sierozems. In both cases the boundary between the light and typical sierozem is less pronounced than that between typical and dark sierozems. A change in bioclimatic conditions takes place here not only in the sub-belt of dark sierozems, but also considerably lower, beginning with the sub-belt of light sierozems. As mentioned by Shchukin (30), "the effect of a mountain region can also be reflected in the natural conditions of neighboring plain areas. As we know, the increase in precipitation, occurring on the windward slopes of the mountains, can begin at a certain distance in the plain at the foot of the slopes."

Foothills and piedmont plains belong definitely to the region where the "law of mountain zonality" is in effect, Liverovskiy and Kornblyum (14) work. These authors suggest that the change in soil in the foothills and piedmont plains, subject to the "indirect influence of mountains" (phenomena of pre-ascending air masses) be considered as a particular regularity within the framework of the foregoing general law in addition to another particular regularity — the vertical zonality of soils along mountain slopes proper, associated with the altitudinal climatic zonality (changes in radiation balance, atmospheric pressure, and air temperature and humidity with increasing absolute elevation). The expediency of contrasting the foothills and piedmont slopes with mountain slopes is doubtful, since pre-ascent phenomena and the associated increase in atmospheric precipitation are not inherent to piedmont plains and foothills alone, but also to mountain slopes, while the elements of altitudinal climatic zonality are manifest not only on mountain slopes, but also in foothills and piedmont plains, because of the considerable elevation amplitude within the limits of the latter (Table 1). Nevertheless, the paper under discussion confirms, on the whole, the necessity of differentiating between the region of vertical zonality and the region of latitudinal zonality by the lower edge of piedmont plains.

The amount of atmospheric precipitation is considerably higher over gentle plains adjoining the high mountain ridges of Central Asia, than over the plains of the Turan lowland. Table 1 gives certain data illustrating this.

At the transition from the Turan lowland to the gentle proluvial or proluvial-alluvial plains, genetically associated with the high mountains, a jump occurs, which is reflected not only in an increase in atmospheric precipitation, but also in a decrease in mean annual temperature, resulting in a sharp increase in relative humidity. The qualitatively new bioclimatic conditions are associated with these changes in climate. A special vegetation develops on the foothill slopes of the Tian-Shan and the Pamirs-Alay, which is being distinguished in the most recent geobotanical papers under the name of low-grass semi-savannahs. "Plant communities in which ephemers and ephemeroids predominate belong to the semi-savannah type... Ephemer-ephemeroid communities cannot be considered as belonging to the steppe type... Ephemer-ephemeroid vegetation cannot be regarded as belonging to meadows, nor to deserts either... (The underlining is ours — authors), Low-grass semi-savannahs are very characteristic of almost all the piedmont plains and foothills of Central Asia... The main element of the plant communities here consists of two small ephemeroids — narrow-leaf sedge (Carex pachystilis), and bulbiferous meadow grass (Poa bulbosa)...in its most typical expression sedge-meadow grass vegetation is characteristic of light sierozems" (22). Semi-savannahs (subtropical steppe) are considered to belong to the group of foothill and mountain vegetation types, which is contrasted with the types of vegetation in valleys and low mountains.[1]

Table 1

Certain elements of the climate of the Turan lowland and the piedmont plains of the Pamirs-Altay system

Name of station	Location: Absolute elevation	Location: Geomorphological elements	Soil	Total annual precipitation, mm	Mean annual temp.	Annual amplitude of mean mthly. temp.	Hydrothermal coeff. (accrd. to Lang)
	Degrees				Degrees, C	Degrees, C	
		Zeravshan River basin					
Shafrikan	240	Turan lowland. Zeravshan delta	Hydromorphous soils in an oasis among gray-br. soils	120	14,2	30,6	3,4
Katta-Kurgan	483	Piedmont valley of the Zeravshan range	Irrigated light sierozems	282	13,0	29,1	21,7
Samarkand	695	Same	Irrigated typical sierozems	328	13,4	26,1	24,5
Urgut	about 1000	Same	Irrigated dark sierozems	459	12,2	24,9	37,6
		Kashka-Dar'ya River Basin					
Kagan	221	Turan lowland. Zeravshan and Kashka-Dar'ya delta	Hydromorphous soils in an oasis among gray-br. soils	125	15,1	31,2	8,3
Karshi	530	Piedmont valley of the Gussar range	Irrigated light sierozems	225	14,8	29,0	15,2
Kitab	658	Same	Irrigated typical sierozems	545	14,7	27,2	37,6

Note: Comma represents decimal point.

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[1] Here we have in mind the small elevations with a mountain relief which are found in the valleys of the Turan lowland and which do not display altitudinal zonality.

Table 2

Humus content in desert zone soils, and in sierozems

Soil and location	Depth, cm	Humus, %
Desert sandy. Kashka-Dar'ya River delta, Profile 1680, Kimberg, 1947	0—4	0,42
	4—24	0,31
	24—55	0,31
Takyr clay loam. Ancient alluvial valley of Kunyadar'ya River, Profile 204, Konobeyeva (11)	0—4	0,32
	4—14	0,29
	14—34	0,32
Gray-brown clay loam. Central Kyzyl-Kum, Tertiary rock outliner, Profile 19, Kimberg, 1956	0—5	0,63
	5—15	0,40
	15—22	0,41
	22—30	0,38
Gray-brown clay loam. Original bank of the Uzboy dry riverbed, Profile 406, Shuvalov, 1951	0—3	0,45
	3—8	0,22
	10—20	0,12
	20—30	0,17
	70—80	0,06
Light sierozem clay loam. Piedmont valley of Turkestan range, Profile 1, Gorbunov (3)	0—5	2,32
	5—10	0,82
	10—20	0,55
	35—45	0,36
	70—80	0,30
Light sierozem clay loam. Piedmont valley of Kopetdag, Profile 326, Ponomareva (18)	0—4	2,46
	4—12	1,50
	12—30	1,15
	30—42	0,37
Clay loam typical sierozem. Foothills of Turkestan range, Profile 4, Gorbunov (3)	0—3	3,93
	5—15	1,11
	20—30	0,53
	50—60	0,46
	80—90	0,28
Clay loam typical sierozem. Foothills of Zeravshan range, Profile 1304, Kimberg, 1947	0—4	2,15
	4—14	0,94
	40—50	0,25
	75—85	0,23
Clay loam dark sierozem. High foothills of Turkestan range, Profile 6, Gorbunov (3)	0—2	5,67
	3—13	2,75
	25—35	0,73
	60—70	0,48

Note: Comma represents decimal point.

The ephemeral-ephemeroidal vegetation of semi-savannahs forms a cover whose density is similar to that of a meadow. The root system of this vegetation forms in the upper 3-5 cm of sierozems a strong, fibrous sod. Wormwood, Russian thistle, and psamophytic-shrub vegetation with subordinate ephemers and ephemeroids is characteristic of the desert plains of Turan. It forms a sparse cover and the soil does not form sod.

The reflection in the soil of these basically different conditions and factors of soil formation in the region of the foothills and piedmont plains of the Tian-Shan and the Pamirs-Alay, as compared to the Turan lowland, has been noted a long time ago. Thus, Neustruyev wrote, "Being an automorphic soil, sierozem is not the soil of Turkestan desert valleys, but rather the soil of the foothills, the first of the vertical zones" (17). Prasolov also believed that "only a relatively small part of Turkestan can be considered as belonging to the sierozem region, namely that discontinuous and unevenly wide belt at the foot of the mountains, on low foothills and large intermountane valleys" (20).

These statements of the first investigators of Central Asian soils were later forgotten and the western lowland-plain part of Central Asia was then also considered as belonging to the "sierozem zone" (with which Neustruyev also agreed). At the same time, new investigations continued to bear witness to the special nature of the belt of foothills and piedmont slopes of the Tian-Shan, Pamirs-Alay, and the Kopetdag and to the difference between the soils of this belt — sierozems — and the soils in the Turan plains.

The differences between the bioclimatic conditions of these two regions are most vividly expressed in the humus profile of the soils. A characteristic feature of sierozems in this respect is the sharply defined maximum of humus in the upper, sod-humus horizon, 3-5 cm thick, which corresponds to the distribution of root masses along the profile (Tables 2 and 3). In contrast to the sierozems, the soils of the desert zone, namely gray-brown soils, desert sandy soils, and takyr soils, are characterized by an even decrease in humus with depth, which reflects the more even distribution along the soil profile of the roots of the predominant wormwood-Russian thistle vegetation. There is also a big difference between sierozems and desert soils in the root and total humus content.

The systematic position of soils in the western desert part of Uzbekistan and of sierozems has been revised in the first volume of the monograph "Soils of the Uzbek SSR" (19). For the first time the western plain part of Uzbekistan and of the entire Central Asia has been definitely established in this work as an individual physiographic region under the name of desert zone, the most southern of the latitudinal zones of the USSR, and distinguished from the former "gray zone." At the same time the remaining part, consisting of the sierozem belt of the piedmont slopes and foothills, beginning with light sierozems, has been related to vertical soil zonality as its lowest member. This found its expression in the regionalization of the hydrological modulus, irrigation regimes, and agricultural crop varieties, and has been confirmed by practice. If the sierozem belt is a dry-farming area, then in the desert zone dry farming is not practiced.

The new status of the soil-geographical division of the desert zone and of the sierozem belt is based on numerous papers of the soil scientists of Tashkent (1, 2, 5, 6, 7, 8, 10, 28). Several other investigators recently began to share this view more-or-less (15, 16, 25, 26). Rozanov (23) proved that there is a difference between the western lowland-plain portion of Central Asia and the foothills and piedmont slopes of its eastern portion. However, after presenting extensive materials on the differences in the conditions of soil formation and soils and even having expressed these differences in a soil classification ("desert sierozem" type for the plains of Turan and "sierozem" type for the foothills and piedmont slopes of the Tian-Shan and the Pamirs-Alay), he nevertheless left the "sierozem zone" within its former boundaries, extending to the foregoing two different physio-

Table 3

Root masses in desert zone soils, and in sierozems

Soil and location	Depth, cm	Root weight over 1 m² area	
		g	% of total amount
Sandy desert. Repetek, Sveshnikova (27)	0—10	140,0	37,9
	10—20	120,4	32,3
	20—30	65,0	17,0
	30—40	46,8	12,8
	0—40	372,2	100
"Overgrowing takyr". Kyzyl-Arvat, Rachkovskaya (21)	0—8	42,3	39,3
	8—11	36,5	33,9
	11—15	22,7	21,1
	15—24	5,0	4,7
	24—36	1,1	1,0
	0—36	107,6	100
Light sierozem. Golodnaya steppe, Kul'tnasov (13)	0—5	1271,6	83,9
	5—10	128,6	8,5
	10—15	50,0	3,3
	15—20	34,0	2,2
	20—25	15,0	0,9
	25—30	5,6	0,4
	30—35	1,5	0,1
	35—40	1,5	0,1
	0—40	1507,8	99,4

Note: Comma represents decimal point.

graphic regions. Our suggestion that the former "gray zone" be divided has been additionally substantiated by Lobova (15, 16).

From the time the systematic list of soils for the State Soil Map of the USSR has been worked out the soil maps being published divide soils into two groups: soils of plain regions and soils of mountain regions. The example of sierozems, examined here, shows that the differentation of soils in the mountain regions according to the orographic principle is in contradiction with the basic soil-geographical principles, such as phenomena of latitudinal and altitudinal soil zonality.

We believe that it is more correct from the point of view of genetic soil science, instead of distinguishing soils of mountain regions, to distinguish soils of the region of vertical zonality and to include in it not only mountain regions with a clearly defined orography, but also regions which are genetically related to the mountains, namely regions of piedmont accumulations — foothills and piedmont plains.

Received February 22, 1961

BIBLIOGRAPHY

1. GENUSOV, A. Z. 1957. Automorphous soils of the desert zone. Khlopchatnik. Vol. 2. Tashkent.

2. GENUSOV, A. Z., B. V. GORBUNOV, and N. V. KIMBERG. 1960. Soil-climatic regionalization of Uzbekistan for agricultural purposes. Izd. UzASKhN, Tashkent.

3. GORBUNOV, B. V. 1942. Main chemical and physical properties of sierozems in the dry-farming zone of Uzbekistan. Tr. Uz. fil. Akad. Nauk SSSR. 10 (5).

4. GORBUNOV, B. V. 1949. Sierozems. In the book: Soils of the Uzbek SR. Vol. 1. Tashkent.

5. GORBUNOV, B. V. 1957. Soils. In the book: Uzbekistan. Geografizdat.

6. GORBUNOV, B. V., N. V. KIMBERG, and S. A. SHUVALOV. 1949. Place of Uzbekistan in the system of the soil-climatic zonality of the USSR. In the book: Soils of the Uzbek SSR. Vol. 1, Tashkent.

7. GORBUNOV, B. V., M. A. PANKOV, and S. A. SHUVALOV. 1957. Soils of the Uzbek SSR. Vol. 2. Tashkent.

8. KIMBERG, N. V. 1949. Desert soils. In the book: Soils of the Uzbek SSR. Vol. 1. Tashkent.

9. KIMBERG, N. V. 1949. Dry-farming land resources of the Uzbek SSR. Izv. Akad. Nauk UzSSR. No. 5.

10. KIMBERG, N. V. 1957. Major soil division. Khlopchatnik. Vol. 2. Tashkent.

11. KONOBEYEVA, G. M. 1959. Changes in the chemical properties of takyr soils in the ancient oases of the Kunyadar plain after irrigation. Uzb. biol. zh. No. 5.

12. KRASNOV, A. N. 1887. Geographical distribution and soil formation in the eastern Tian-Shan. Tr. SPb. o-va yestestvoispyt. Vol. 18.

13. KUL'TIASOV, M. V. 1927. Vertical vegetation zones in the Western Tian-Shan. Byul. Sredneaz. gos. un-ta. No. 14-15.

14. LIVEROVSKIY, YU. A. and E. A. KORNBLYUM. 1960. Soil zonality in foothill regions. Izv. Akad. Nauk SSSR, ser. geogr. No. 3.

15. LOBOVA, YE. V. 1956. Soils of the desert zone of the USSR. VI International Congress of Soil Science. Izd. Akad. Nauk SSSR.

16. LOBOVA, YE. V. 1957. Problem of the differentiation of the desert zone and its division into provinces. In: Collection devoted to the memory of L. I. Prasolov. Izd. Akad. Nauk SSSR.

17. NEUSTRUYEV, S. S. 1913. Outline of the nature and history of the Namangan district. In the book: Materials on land use in Kirgizia. Pereselench. upravl. GUZiZ. Tashkent.

18. PONOMAREVA, V. V. 1956. Takyr humus. Takyrs of Western Turkmenia and methods for their agricultural reclamation. Izd. Akad. Nauk SSSR.

19. Soils of the Uzbek SSR. Vol. 1. 1949. Izd. Akad. Nauk UzSSR, Tashkent.

20. PRASOLOV, L. I. 1925. Soils of Turkestan. Leningrad.

21. RACHKOVSKAYA, YE. I. 1956. Underground portion of takyr plant communities and desert semi-shrubs of Southwestern Turkmenia. Takyrs of Western Turkmenia and methods for their agricultural reclamation. Izd. Akad. Nauk SSSR.

22. RODIN, L. YE. and N. I. RUBTSOV. 1958. Vegetation. Types of vegetation. In the book: Central Asia. Moscow.

23. ROZANOV, A. N. 1951. Sierozems of Central Asia. Moscow.

24. ROZANOV, A. N. 1958. Soil. Central Asia. Moscow.

25. ROZOV, N. N. 1954. Principles of the natural regionalization of the USSR for agricultural production purposes. Pochvovedeniye. No. 8.

26. ROZOV, N. N. 1956. Soil map of the USSR. Papers presented at the VI International Congress of Soil Science. V Commission. Moscow.

27. SVESHNIKOVA, V. M. 1955. Root systems of ephemers and ephemeroids in the Kara-Kum. Tr. Repetekskoy peschano-

pustynnoy stantsii. Vol. 3. Ashkhabad.

28. SUCHKOV, S. P. 1950. Soils of the cotton-growing regions of Uzbekistan. Tashkent.

28. FRIDLAND, V. M. 1951. Experimental soil-geographic division of mountain systems in the USSR. Pochvovedeniye No. 9.

30. SHCHUKIN, I. S. and O. YE. SHCHUKINA. 1959. The life of mountains. Moscow.

MECHANISM OF ARTIFICIAL STRUCTURAL FORMATION

G. L. MASLENKOVA

High-molecular substances are being used more and more in agriculture. Some of them are successfully used for creating an artificial soil structure. The structural-forming polymers known in the Soviet Union include: polyacrylamide, copolymer VIII (60% metacrylic acid and 40% metacrylamide), and hydrolyzed polyacrylinitrile. Certain firms abroad manufacture several tens of structural-forming polymers (13).

Structural-forming polymers have certain common properties: firstly, they are all soluble in water under certain conditions; secondly, they structuralize the soil to a greater or lesser degree; and thirdly, they have, as a rule, functional groups, such as hydroxyl, carboxyl, amide, nitrile, phenyl, etc. But at the same time they differ essentially from each other. There are polycations, polyanions, and neutral polymers among structural-forming polymers. The majority of the polymers used are polyanions.

Numerous experimental facts show that structural-forming polymers do not have the same ability for creating a water-stable macrostructure (7). It also proved that one and the same polymer behaves differently on different soils (6).

In order to use structural-forming polymers more efficiently, we must determine, first of all, how the polymers interact with the soil particles. Only after we have determined the mechanism of artificial structural formation will we be able to solve the problem of what properties a polymer must possess for optimum structural formation.

A great number of papers are devoted to the study of the problem of the mechanisms of interaction between polymers and soil particles (7), but nevertheless this problem remains unsolved as yet. The difficulty lies in that, as a rule, individual investigators work with various soil samples and various structural-forming polymers. Therefore, the conclusions we can derive from such type of work are of a rather particular nature. It is true that the majority of papers make more general conclusions on the mechanism of the interaction between structural-forming polymers and soil particles, which, unfortunately, are not born out by experiments. In order to determine the general principles and to understand the mechanisms of artificial structural formation we must work with a pure material which is contained in the majority of soils. The main component of soils is clay minerals. Therefore we used kaolinite in our investigations. From the results of X-ray analysis we know that the interaction between polymers-polyanions with particles of clay minerals (kaolinite and montmorillonite) is a surface phenomenon (14). In the case of polycations and neutral polymers, however, there is a certain difference in the interaction between the polymers and montmorillonite, since macromolecules are capable of penetrating between the layers of the crystal lattice of this mineral. Infrared absorption spectra (8) show that the nature of the bonds forming in montmorillonite is the same as in kaolinite, but the formation of hydrogen bonds is more pronounced in the infrared spectrum of kaolinite (4). By working with kaolinite we immediately eliminate the difficulties in the understanding of the mechanism of structural formation. We eliminate the role of the mineralogical and to a certain degree of the textural and chemical composition of soils.

The structural-forming effect of polymers depends to a large degree on the size and form of macromolecules, the degree of their branching the number and type of active functional groups, the number of these groups per unit of the polymer chain, and their distribution in the polymers (11). In order to establish the relationship between the structural-forming effect, the form of macromolecules and the number and type of active functional groups, polyacrylamide of various degrees of hydrolysis has been used (9).

The process of the interaction between polymers and soil particles is usually accompanied by a number of phenomena: flocculation, adsorption, and the formation of hydrogen bonds. These phenomena are most likely superimposed upon each other, and, possibly, govern each other. As a result of the interaction between polymer molecules and soil particles a water-stable macrostructure forms. In order to understand the reasons for its formation all these phenomena must be studied individually and then by comparing the results obtained we can determine to what degree one or the other phenomenon is responsible for the formation of water-stable macroaggregates.

EXPERIMENTAL PROCEDURE

We hydrolyzed polyacrylamide in a 2-N solution of NaOH at 100°C by varying the duration of hydrolysis from 5 min to 4 hr, in conformity with the kinetic curve of polyacrylamide hydrolysis given in the paper of Fu Hsin-t'o and T'ieh Chu-k'ou (5). We obtained seven polymers of various degrees of hydrolysis -- from 10% to 70%. The degree of hydrolysis is characterized by the ratio between the amount of nitrogen released in the form of ammonia and the content of nitrogen in the initial solution. The degree of hydrolysis of polyacrylamide was controlled by measuring the total content of nitrogen in the polymer by the Kjeldahl micromethod.

In order to study flocculation, polyacrylamide (of a given degree of hydrolysis) of various concentration was added to the 4% kaolinite suspension. After polyacrylamide was added to the water suspension the concentrations of polymer solutions were the following: 10^{-1}, 5×10^{-2}, 10^{-2}, 5×10^{-3}, 10^{-3}, 5×10^{-4}, 5×10^{-5}, and 10^{-5}%.

The suspension was shaken, allowed to settle for an hour, and then the turbidity of the solutions was measured in a nephelometer and the size of the flocculated particles was measured in an MIR-12 microscope, while the sedimentation volume was read from the graduated test tubes used for the study of flocculation.

In order to obtain the adsorption isotherm 0.05% solutions of polyacrylamide were prepared in amounts of 200 cm^3. Various samples of kaolinite, ranging from 50 to 2 g, were placed in these solutions. The suspensions were shaken for 8 hours, centrifuged, and the concentration of the solutions obtained was determined by the weighing method.

One and the same sample of kaolinite (20 g) was added to a 0.05% solution of polyacrylamide in order to study adsorption in relation to the molecular weight of the polymer.

The samples were prepared in the following manner to obtain infra-red adsorption spectra. A 0.1% solution of polyacrylamide was poured in a 100 cm^3 cylinder and 100 mg of kaolinite were placed in it. The contents of the cylinder were thoroughly mixed several times in 2-3 days, then dried and crushed in a shaker, and then used for analysis. The spectra were taken in infrared IKS-11 spectrometer and recorded on an electronic EPP-09 potentiometer with the aid of an FEOU-18 amplifier. We used a sodium chloride prism.

Water-stability was determined by the modified method of Savvinov (the wetting of the soil in the cylinder was eliminated).

RESULTS OF INVESTIGATIONS

The structural-forming capacity of the polymers was studied in relation to the amount of various functional groups, and, therefore, on the form of macromolecule, on 8 polymers: with non-hydrolyzed polyacrylamide and with polyacrylamide hydrolyzed to 10%, 20%, 30%, 40%, 50%, 60%, and 70%.

When studying flocculation we obtained curves for turbidity, particle size, and the magnitude of the sediment in relation to the concentration of polymers (Fig. 1-A and -B). The process of flocculation (2% kaolinite suspension) is best expressed at polyacrylamide solution concentra-

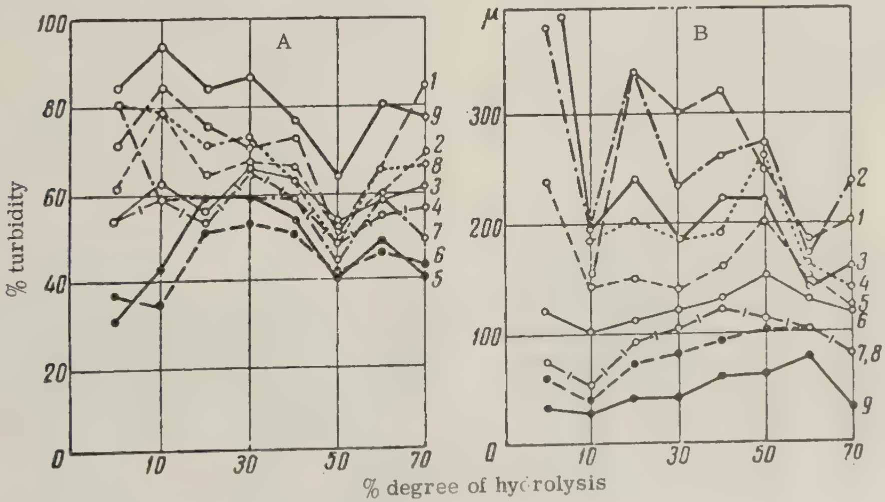

Fig. 1. - Relationship of suspension turbidity (A) and size of flocculated particles (B) to the degree of hydrolysis of polyacrylamide.
Concentration of polyacrylamide, %: 1 - 10^{-1}; 2 - $5 \cdot 10^{-2}$; 3 - 10^{-2}; 4 - $5 \cdot 10^{-3}$; 5 - 10^{-3}; 6 - $5 \cdot 10^{-4}$; 7 - 10^{-4}; 8 - $5 \cdot 10^{-5}$; 9 - 10^{-5}.

tions of 10^{-3} and 5×10^{-4}%. At these concentrations the non-hydrolyzed polymer flocculates best.

The intensity of flocculation decreases with increasing degree of hydrolysis, i. e., with the increasing number of carboxyl groups and, consequently, with the increasing number of negatively-charged groups which push apart the macromolecule. Least flocculation takes place at 30% hydrolysis of the polymer. With the further increase of the degree of hydrolysis up to 50% flocculation increases. If we compared the turbidity curves at other polymer concentrations we can see that they are of a somewhat different nature, but nevertheless show common patterns. Firstly, all curves exhibit to a greater of lesser degree a turbidity maximum at 30% hydrolysis, i. e., worst flocculation, while flocculation is best at 20% and 50% hydrolysis.

If we compare these patterns with particle-size curves (Fig. 1-B), we can see that the least the turbidity, the larger the particles formed. The size of the particles increases with increasing polymer concentration for all polymers of various degrees of hydrolysis.

We also analyzed the relationship between the sedimentation volume and the degree of hydrolysis of the polymer. As was to be expected, the largest sedimentation volume was obtained at polymer concentrations giving the best flocculation. The maximum value of sedimentation was obtained at 30% and 40% hydrolysis, i. e., the most favorable form of polymer molecules for interaction with kaolinite.

In studying the infrared spectra of kaolinite, treated with the polymers, we showed that a hydrogen bond forms during the interaction between structural formers and soil particles (4). As we know, kaolinite has a layered structure and hydroxyl groups are located at the contact between each package of layers. Structural-forming polymers also contain groups which are capable of creating a hydrogen bond, such as carboxyl or amide groups. Consequently, during the interaction of the polymers with kaolinite hydrogen bonds of the type OH..O and OH..N may form. In the present investigation we studied the capacity of all the polymers listed previously to form a hydrogen bond with kaolinite.

Figure 2 shows the relationship of the relative intensity[1] of the free hydroxyl line in the transmission spectrum of kaolinite, treated with the polymers, to the degree of hydrolysis of the polymer. It proves that polyacrylamide with a 30% hydrolysis forms the largest number of hydrogen bonds with kaolinite. The capacity to form a hydrogen bond with kaolinite drops sharply in polymers with a degree of hydrolysis of 20% and 50%.

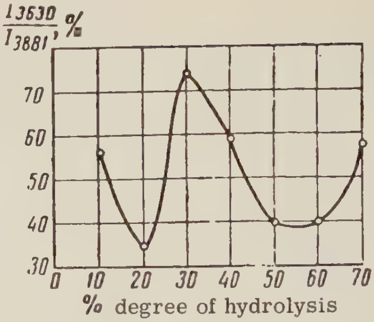

Fig. 2. - Relationship of the relative intensity of the free kaolinite hydroxyl line to the degree of hydrolysis of polyacrylamide.

Table 1

Data on the water-stability of macroaggregates, flocculation and the adsorption of kaolinite by non-hydrolyzed polyacrylamide

η	Turbidity, %	Water-stability, %	Adsorbed, mg/g
5,65	50	40	1,8
5,8	70	52	1,06
6	30	20	2,3
7,38	77	40	1,65

Note: Comma represents decimal point.

When comparing this curve with Figure 1-A and -B, we can easily see that the better flocculation the less is the number of hydrogen bonds formed. The greatest number of hydrogen bonds forms with the worst flocculation, i. e., at 30% hydrolysis.

The adsorption isotherm was obtained for non-hydrolyzed polyacrylamide. The adsorption of polyacrylamide is not limitless, and even with 25 mg of the polymer in the solution only 3 mg of the structural former are adsorbed by 1 g of kaolinite.

In order to study the relationship of the water-stability of macroaggregates to the degree of hydrolysis of the polymer, kaolinite was structuralized with polymers of various degrees of hydrolysis. The polymers were used in amounts corresponding to 0.4% of the weight of the mineral. A rather large amount of polymer was used since the degree of aggregation depends on specific surface, which is of the order of 20 m² per gram for kaolinite, according to the data of many investigators (10).

The largest percentage of water-stable aggregates (95%) was also obtained with a degree of polymer hydrolysis of 30%. The minimum percentage of water-stable aggregates (58%) was obtained with the non-hydrolyzed polymer. It must be noted, however, that the same percentage of water-stability is obtained from a polymer with a 30% hydrolysis when the polymer is used in an amount equal to 0.05% of the weight of kaolinite.

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[1] We took the relative intensity of the free hydroxyl line in order to eliminate scattering caused by powder-like materials.

In summing up the foregoing experimental results, we must note that on the one hand the worst flocculation occurs with a 30% hydrolysis of the polymer (maximum turbidity and minimum particle size), while on the other hand the largest amount of hydrogen bonds and the largest percentage of water-stable aggregates form.

Similar studies were conducted with non-hydrolyzed polyacrylamide of varying molecular weight and a characteristic viscosity η = 5. 65, 5. 8, 6, and 7. 38. The polymers had very similar characteristic viscosities, i. e., they differed little in molecular weight, but still we were able to discover differences in their aggregation capacity.

If we compared the data on water-stability, flocculation (turbidity), and adsorption (Table 1), we can see that water-stability is inversely related to flocculation and adsorption.

As we have seen, similar regularities were obtained for polymers of varying degrees of hydrolysis. We have not studied their adsorption yet, but judging by the data of other investigators (12) we can assume that the less ionized groups a polymer contains, the more its molecules are twisted in a knot (2, 1) and the more of the polymer kaolinite adsorbs. In our case the non-hydrolyzed polyacrylamide is adsorbed the best, but it, in effect, gives the best flocculation, on the one hand, and the least percentage of water-stable aggregates, on the other hand. As polyacrylamide is hydrolyzed flocculation deteriorates initially. We should also expect a decrease in the adsorption of the polymer on kaolinite, because the molecules acquire an ever greater number of carboxyl groups as the degree of hydrolysis of polyacrylamide increases. These groups in turn turn partly dissociate the molecule and in doing this increase its size and charge. As a result the molecule does not adsorb as well on kaolinite, but at the same time, as a result of the rupture of intra-molecular hydrogen bonds, a large amount of free functional groups forms, which are capable of forming hydrogen bonds with the surface of clay particles. We observed this from the infrared spectra. As we have seen, a larger percentage of water-stable aggregates forms thereby.

Consequently, in order for a water-stable structure to form the amount of polymer adsorbed by kaolinite is not as important as the number of bonds forming between them. When the degree of hydrolysis of the polymer is increased to above 30%, there is a certain increase in the floculation capacity of polyacrylamide, especially at a 50% hydrolysis.

If the flocculation of kaolinite by non-hydrolyzed polyacrylamide is achieved at the expense of the adsorption of positively-charged macromolecules by the negatively-charged clay particles, then flocculation at higher degrees of hydrolysis and greater negative charges of macromolecules is apparently due to the presence in the solution of simple electrolytes (counter-ions), which appear as a result of the dissociation of carboxyl groups (10).

We must remember that flocculation and adsorption, as well as the formation of hydrogen bonds (during the preparation of the sample) were studied in a strongly diluted suspension. Soil under natural conditions as well as during artificial structure formation never contains so much water. Therefore we believe that flocculation may be somewhat impaired during slight wetting. Maybe this is the explanation for the fact that the minimum in the curves in Figure 1-A and 2 is lacking in the water-stability curve.

Moistening causes the particles in dry, pulverized soil to stick together, whereby meniscus forces arise between the particles and microaggregates, which hold the soil particles together (3). Therefore, soil can also be aggregated with water, but the aggregates forming as a result of such treatment are not water stable. If instead of water we use a polymer solution, then water-stable aggregates form as a result of the formation of hydrogen bonds between the functional groups of the polymer and the surface of soil particles.

Conclusions

1. Polyacrylamide with a degree of hydrolysis of 30% has the optimum structural-forming properties.

2. The formation of water-stable macroaggregates is inversely related to the flocculating capacity of the polymer and its adsorption, and is achieved through the hydrogen bond.

3. The formation of microaggregates is in direct relationship with the flocculating capacity of polyacrylamide and its adsorption.

4. The mechanism and processes governing the formation of microaggregates are quite different from those determining the formation of macroaggregates (which has been defied by certain authors up to this time).

BIBLIOGRAPHY

1. ALDOSHIN, V. G., M. N. SAVITSKAYA, and S. YA. FRENKEL'. 1960. Certain physicochemical characteristics of high-molecular polyacrylamide. Vysokomolekul. coyedineniya. No. 3.

2. BRESLER, S. YE. 1957. Polymer electrolytes. Progress in the chemistry and technology of polymers. Goskhimizdat. Moscow.

3. VERSHININ, P. V. 1957. Problems of soil structure. Vopr. agron. fiz.

4. MASLENKOVA, G. L. 1960. Investigations on the structural-forming properties of polymers by infrared spectroscopy. Byul. nauchno-tekhn. inform. po agron. fiz. No. 8-9.

5. FU HSIN-T'O and T'IEH CHU-K'OU. 1959. Hydrolysis of polyacrylamide and its copolymers. Khimiya i tekhnol. polimerov. No. 5.

6. ALLISON, L. E., D. C. MOORE. 1956. Effect of VAMA and HPAN Soil Conditions on Aggregation. Surface Cructing and Moisture Retention in Alkali Soils. Soil. Sci. Soc. America Proc. v. 20, p. 147.

7. FIEDLER, H. J. 1956-1957. Über die Wirkung organischer Polyanionen und Polykationen auf Bodenbestandteile und Böden, Wiss. Z. Friedrich-Schiller Univ. Math.-naturwiss. Reihe, B 6, No. 5-6 S, 391.

8. HOLMES, R. M. and S. J. TOTH. 1957. Physico-Chemical Behavior of Clay-Conditioner Complexes, Soil Sci. v. 84, No. 6, p. 479.

9. MICHAELS, A. S. 1954. Aggregation of Suspensions by Polyelectrolytes, Industr. and Engng Chem. v. 46, p. 1485.

10. MICHAELS, A. S. and O. MORELOS. 1955. Polyelectrolyte Adsorption by Kaolinite. Industr. and Engng. Chem. v. 47. No. 9.

11. MONTGOMERY, R. S. and B. B. HIBBARD. 1955. Theoretical Aspects of the Soil-Conditioning Activity of Polymers. Soil Sci. v. 79, No. 4.

12. MORTENSON, J. L. 1959. Adsorption of hydrolyzed polyacrylnitrile on kaolinite. Soil Sci. Soc. America Proc. vol. 23, No. 3.

13. MOWRY, D. T., R. M. HEDRICK. 1953. a. b. U. S. Patent 2, No. 625, p. 471, 529.

14. RUEHRWEIN, R. A., D. W. WARD. 1952. Mechanism of clay aggregation by polyelectrolytes. Soil Sci. v. 73, p. 485.

EFFECT OF VARIOUS METHODS OF TILLING SLOPE SOILS ON THEIR MOISTURE, NUTRIENT REGIME, AND THE YIELD OF BARLEY

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One of the most important ways of improving soil utilization in the central chernozem zone is the organization of soil erosion control. Because of the highly dissected relief, especially on the right bank of the Don River, and the high degree of soil cultivation, erosion in this zone is widespread (9).

The soil moisture dificit is compensated for by autumn-winter precipitation, but a large part of it (60%-80%) runs off into gulches and ravines in the form of meltwater, removing the fertile layer of soil (10). The yield of agricultural crops on such soils is reduced 2-4-10 times and more, depending to the degree of soil erosion (12, 4, 6).

Plants are not sufficiently supplied with nutrients on slopes as a result of intense meltwater runoff and the removal of nutrients (1, 11, 13). Under such conditions methods of soil tillage are of great importance in the regulation of spring runoff.

The effect of the basic soil tillage on the reduction of runoff, the decrease of erosion, and the increase of the yield of agricultural crops in the zone under study was clarified by Kozmenko (5), Presnyakova (7, 8), Yarovenko, Suchalkina, and Aliyev (15), Ginaylo (3), Tsyganov (14), and others. These authors came to the conclusion that diking, basin furrowing, intermittant ridging, and mole plowing of slopes not only retains runoff and prevents the removal of nutrients from the soil, but also increases the yield of agricultural crops by 1.5-2 cntr/ha, and that of forage crops by much more.

Positive results were also obtained in a 3-year experiment by cultivating the soil without a moldboard to a depth of 35-40 cm after the stubble had been subtilled as compared to usual plowing (to a depth of 22 cm) in the fields of the Dokuchayev Institute of Agriculture in the Central Chernozem Zone. It has been established that on 3° slopes with slightly eroded soils, free of weeds, plowing without a moldboard reduces melt runoff 2-4 times, increases soil moisture by 2%-3%, and increases the yield of spring wheat, oats, and barley by 2-4 cntr/ha.

A two-year experiment (1954-1955) with ordinary plowing and the creation of micro-basins showed that such treatment increases the yield of millet and oats by 2 cntr/ha and the amount of moisture in the soil by 20-30 mm. However, the problems of moisture dynamics, nutrient regime, and the physical properties of soils after various methods of tillage have not been studied sufficiently.

Beginning in 1957 the authors of the present paper continued the study of the influence of various methods of soil tillage on slopes on moisture dynamics, the nutrient regime, and the productivity of agricultural crops.

As compared with earlier investigations, the experiments included new treatments: 1) without plowing in autumn in order to conserve the stubble of the harvested crop; and 2) ordinary plowing to a depth of 20-22 cm, and subsoiling to a depth of 15 cm.

The experiments were replicated twice. The size of the plots was 0.4 ha. The slope was 3°. The soil was ordinary chernozem with a humus layer 40 cm thick.

In order to conduct field observations and take soil samples in the first experiment, an area 50 m² was selected in each plot (in its central part).

The bulk density of the soil in the layers from 0-10 cm, 10-22 cm, and 22-40 cm was determined by the usual method (500 cm³ cylinder). Particle density was determined in duplicates by means of a pycnometer. Soil porosity, shown in Table 1, was determined by calculation using the usual method. Soil moisture was determined by the weighing method. Soil samples were taken 3 times from each layer of plowed soil to a depth of 1 m.

Nitrates were determined by the Grandval-Lajou method, and phosphoric acid, by the Truog method. Soil samples for these analyses were also replicated 3 times. From the average composite sample from each of the layers (0-10 cm, 10-22 cm, and 22-40 cm) two soil samples were taken for further laboratory investigation. The NO_3 and P_2O_5 were determined in moist samples.

The barley yield in 1958 was assessed by the

Table 1

Soil porosity (%) under barley after various methods of soil tillage (determined before sowing)

Method of plowing	Depth of cultivation, cm	In the layer from 0-40 cm		
		27. IV. 1958 r.	14. IV. 1959 r.	12.IV. 1960 r.
Spring plowing··	20—22	70,5	70,4	70,4
Ordinary plowing (control)	20—22	69,1	69,1	69,9
Same + ridges and dikes	20—22	70,4	73,4	69,0
Same + soil deepening	20—22+15	71,9	72,9	73,5
Without a moldboard + stubble (10-15 cm)	35—40	72,1	71,4	71,2

Note: Comma represents decimal point.

separation method, while in 1959 and 1960 it was assessed by direct combining (C-4 combine). This yield is presented by years in Tables 6 and 7, as reduced to 14% moisture and granary purity.

The determination of soil porosity (Table 1) showed that most of the friability remained in the plots which were deeply cultivated without a moldboard and in plots plowed in the ordinary way with subsoilers.

Three-year data on moisture dynamics (Table 2) showed that plants were better supplied with moisture during the crucial phases of development in plots where the soil was cultivated deeply without a moldboard and in those which were plowed and whose soil was deepened than in the control. The only exception to this was in 1960. The differences in moisture were especially pronounced in the dry year of 1959, when there was 19 mm more moisture in the upper 1 m of soil during the phase of full sprouting in the plot cultivated with subsoilers than in the control, 13 mm more moisture in the plot plowed without a moldboard, and 4 mm in the plot with the micro-basins. During the tillering phase there was 30 mm, 49 mm, and 32 mm more moisture in the foregoing plots, respectively, than in the control. During the phase of grain formation there was more moisture in only two plots as compared to the control, in the plot plowed in the ordinary way with subsoilers and in the plot with the micro-basins, which amounted to 19 mm in the first and 31 mm in the second.

The dynamics of nitrates in the soil was determined by phases of plant development. As we can see from Table 3, there were more nitrates in the layer from 0-10 cm, which was warmed during the presowing period. During the full sprouting nitrate content increased in the layer from 0-40 cm, while during the tillering period it decreased (more during the moist year of 1958, and less during the dry years 1959 and 1960). During the following phases of plant development the process of nitrate accumulation was approximately the same. During the following phases of plant development the process of nitrate accumulation was approximately the same. During the years of study, except in 1960, the plants were supplied with the necessary amount of nitrogen in the form of nitrate for a good crop in all the plots. Plots cultivated with a plow and subsoiler and without moldboards had a considerable advantage with respect to nitrate content in 1959 and 1960.

There was no consistent difference in phosphorus in the variously cultivated plots and the plants were well supplied with it during all their phases of development.

The amount of phosphorus, as that of nitrates, decreased with depth, independently of the method or depth of soil cultivation, the phase of plant development, and moisture in the given year.

In 1959 we determined the residual effect of soil cultivation on the basis of the experiment in the preceding year. In autumn the slope was cross-plowed to a depth of 20-22 cm and dikes were made.

Observations showed (Table 4) that at the beginning of the wax ripeness of barley there was a residual effect with respect to moisture in only one of the plots — that where the microrelief was modified during cultivation.

The residual effect was most favorable with respect to nitrates in the plot which was subtilled, even though in the main experiment of 1959 this plot did not differ from the others. The supply of nitrates to plants was better in the plot cultivated with subsoilers and in that subtilled than in the control (Table 5).

The residual effect of deep plowing without moldboard stood out by the amount of phosphorus in the soil during the tasseling phase. In the other plots there was no residual effect from the method of soil tillage on the increase in the content of phosphoric acid.

Crop yield data (Table 6) show that under the dry conditions of the southeastern part of the central chernozem zone the yield increment per hectare is practically the same and the absolute yield is higher on 3° slopes plowed with subsoilers and deeply subtilled without a moldboard

Table 2

Moisture dynamics under barley after various methods of cultivation, mm

Method of plowing, and depth, cm	Time of determination								
	Sprouting			Tillering			Grain formation		
	Depth, cm								
	0—22	0—40	0—100	0—22	0—40	0—100	0—29	0—40	0—100
1958									
	16.V			5.VI			11.VII		
Spring plowing (20-22)	60	103	262	33	60	211	72	124	278
Ordinary plowing (20-22) (control)	54	101	294	28	59	213	71	123	284
Same + ridges and dikes (20-22)	61	105	286	33	64	216	73	122	297
Same (20-22) + soil deepening (15)	62	108	294	34	65	219	67	117	279
Without a moldboard (35-40) + stubble (10-15)	58	105	294	35	71	233	77	134	312
1959									
	5.V			21.V			29.VI		
Spring plowing (20-22)	52	91	258	39	79	257	39	72	196
Ordinary plowing (20-22) (control)	49	88	262	32	51	220	42	77	184
Same + ridges and dikes (20-22)	50	91	266	40	78	252	43	80	215
Same (20-22) + soil deepening (15)	54	94	281	37	73	250	38	73	203
Without a moldboard (35-40) + stubble (10-15)	49	97	275	40	81	262	40	57	183
1960									
	8.V			11.VI			4.VII		
Spring plowing (20-22) + stubble (10-15)	65	113	307	48	89	264	31	59	184
Ordinary plowing (20-22) (control)	59	105	291	42	80	260	28	53	172
Same + ridges and dikes (20-22)	71	121	300	50	95	257	31	62	185
Same (20-22) + soil deepening (15)	56	102	286	38	72	232	27	51	171
Without a moldboard (35-40) + stubble (10-15)	62	101	286	50	83	256	28	49	163

plow as compared to the control.

The effectiveness of these methods of tillage is retained in their residual effect (Table 7). As we can see from the foregoing data, plowing in spring and the cultivation of soil on slopes does not give negative results. This is attributable to the positive effect of stubble in snow retention and the higher moisture content in the layer from 0-40 cm during the growing period.

In generalizing the results obtained, we may conclude that deep plowing on slopes is more effective in erosion control, but plowing to a depth of 20-22 cm and deepening the soil to 37 cm is more economical.

Conclusions

1. The plowing of soils on east and southeast 3^{0} slopes with slightly eroded soils to a depth of 20-22 cm and soil deepening by 15 cm and plowing to a depth of 40 cm without a moldboard increases soil porosity and improves the water and nutrient regime for cultivated plats as compared to ordinary plowing to a depth of 20-22 cm.

2. A modification of the micro-relief of plowed fields improves the water regime of the soil and its physical properties, but is ineffective as far as the supply of nitrogen and phosphorus to plants is concerned.

Table 3

Dynamics of NO_3 under barley after various methods of soil tillage (mg/kg of absolutely dry soil)

Method of plowing and depth, cm	Time of determination								
	Sprouting			Tillering			Grain formation		
	Depth, cm								
	0—10	10—22	22—40	0—10	10—22	22—40	0—10	10—22	22—40
	1958								
	May 16			June 5			July 11		
Spring plowing (20-22)	110	19	27	6	8	4	5	5	Trace
Ordinary plowing (20-22) (control)	113	66	24	9	9	4	7	8	4
Same + ridges and dikes (20-22)	131	33	28	4	9	4	5	6	4
Ordinary plowing (20-22) + soil deepening (15)	147	46	71	4	4	Trace	7	6	3
Without a moldboard (35-40) + stubble (10-15)	154	27	23	31	47	23	5	6	Trace
	1959								
	May 5			May 21			June 29		
Spring plowing (20-22)	18	42	10	50	66	11	64	26	9
Ordinary plowing (20-22) (control)	81	79	21	16	24	12	22	14	Trace
Same + ridges and dikes (20-22)	51	53	22	8	21	11	22	16	8
Ordinary plowing (20-22) + soil deepening (15)	152	127	28	28	38	18	60	18	9
Without a moldboard (35-40) + stubble (10-15)	57	19	60	23	21	33	69	24	11
	1960								
	May 8			June 1			July 4		
Spring plowing (20-22) + Stubble (10-15)	19	18	21	12	10	11	15	8	4
Ordinary plowing (20-22) (control)	17	19	20	8	10	6	9	7	4
Same + ridges and dikes (20-22)	17	26	31	9	11	6	10	5	4
Ordinary plowing (20-22) + soil deepening (15)	13	27	57	6	10	7	14	5	4
Without a moldboard (35-40) + stubble (10-15)	19	32	26	7	7	5	9	4	4

Table 4

Soil moisture (mm) in the 1958 experiment during determination of residual effect in 1959

Method of plowing and depth, cm	Booting			Grain formation		
	Depth, cm					
	0—22	0—40	0—100	0—22	0—40	0—100
Spring plowing (20-21)	39	74	235	38	73	199
Ordinary plowing (20-22) (control)	32	64	206	38	71	198
Same + dikes and ridges (20-22)	39	75	235	42	80	239
Same (20-22) + soil deepening (15)	34	69	229	37	70	205
Without a moldboard (35-40) + stubble (10-15)	32	63	223	38	72	199

Table 5

Amount of NO_3 in the 1958 experiment during determination of residual effect in 1959 (mg/kg of absolutely dry soil)

Method of plowing and depth, cm	Booting			Grain formation		
	Depth, cm					
	0—10	10—22	22—40	0—10	10—22	22—40
Spring plowing (20-22)	12		Traces	83	30	16
Ordinary plowing (20-22) (control)	10	10	8	20	21	Trace
Ordinary plowing + dikes and ridges (20-22)	14	9	Traces	29	21	12
Same (20-22) + soil deepening (15)	41	33	16	44	19	11
Without a moldboard (35-40) + stubble (10-15)	33	93	Traces	53	25	9

Table 6

Effect of soil tillage on yield of Nutans 187 barley

Method of plowing and depth, cm	Grain								
	1958			1959			1960		
	cntr/ha	Mean error	Incr. cntr/ha	cntr/ha	Mean error	Incr. cntr/ha	cntr/ha	Mean error	Incr. cntr/ha
Spring plowing (20-22) + stubble (10-15)	30,7	0,5	0,5	12,0	1,0	—0,0	30,3	1,2	2,5
Ordinary plowing (20-22) (control)	30,2	0,0	—	12.0	0,0	—	27,8	1,6	—
Same + dikes and ridges (20-22)	32,3	0,2	2,1	13,6	1,4	1,5	30,0	0,3	2,2
Same (20-22) + soil deepening (15)	34,4	0,0	4,2	14,6	1,5	2,6	28,8	0,5	1,0
Without a moldboard (35-40) + stubble (10-15)	31,5	0,5	1,3	15,0	1,1	3,0	26,1	0,8	—1,7

Note: Comma represents decimal point.

Table 7

Residual effect of various methods of basic soil tillage on barley yield

Method of plowing and depth, cm	1959		
	Cntr/ha	Mean error	Increment, cntr/ha
Spring plowing (20-22) + stubble (10-15)	17,4	0,9	0,2
Ordinary plowing (20-22) (control)	17,2	0,1	—
Same + dikes and ridges (20-22)	14,8	0,8	—2,4
Same (20-22) + soil deepening	19,3	0,0	2,2
Without a moldboard (35-40) + stubble (10-15)	20,1	0,6	2,9

Note: Comma represents decimal point.

3. As in the first year of cultivation, the residual effect of plowing with subsoilers, plowing without a moldboard, and the modification of the micro-relief of the plowed field on the crop yields is higher that in the control.

Plowing with subsoilers is the most economical method of all.

Received March 5, 1960

BIBLIOGRAPHY

1. BITYUKOV, K. K., M. N. MIKHAYLOV, and V. YA. POPOVA. 1953. Methods of accumulating and conserving moisture in the soil. Moscow.
2. VIL'YAMS, V. R. 1936. Soil science. General agriculture with the principles of soil science. Moscow.
3. GINAYLO, F. T. 1958. Mole plowing of soil — an important factor in the increase of productivity. Kursk.
4. KOZMENKO, A. S. 1949. Soil erosion control. Moscow.
5. KOZMENKO, A. S. 1937. Studies by the Novosil'sk experiment station of methods of erosion control. Moscow-Leningrad.
6. PRESNYAKOVA, G. A. 1945. Influence of the degree or erosion (soil removal) on the yield of agricultural crops. Pochvovedeniye. No. 8.
7. PRESNYAKOVA, G. A. 1955. Diking and ridging of autumn-plowed fields as a measure of soils erosion and drought control. Pochvovedeniye. No. 2.
8. PRESNYAKOVA, G. A. 1957. Agricultural practices in the control of water erosion in the Altay Province. Erosion control and prevention in areas of virgin land and layland reclamation. Moscow.
9. SKACHKOV, I. A. 1959. Agricultural problems and soil erosion control in the steppe and forest-steppe regions of the USSR. Vol. 1. VASKhNIL, Saratov.
10. SKACHKOV, I. A. and M. I. SUCHALKINA. 1959. Soil erosion control in the Central chernozem belt. Voronezh.
11. SOBOLEV, S. S. 1956. Control of the water and wind erosion of soils in the USSR. (Results of the VI All-Union Conference on Soil Erosion Control, December 12-16 1955, In Moscow). Pochvovedeniye, No. 7.
12. SOBOLEV, S. S. 1958. Soil erosion control. Ser. V. Moscow.
13. TERESHCHENKO, I. S. 1955. Increase of productivity and soil erosion control by means of the retention of meltwater by dikes. Tr. Pochv. in-ta im. V. V. Dokuchayeva. Vol. 10.
14. TSYGANOV, M. S. 1958. Increase of the productivity of land on slopes — an important means of increasing the productivity of grassing areas and pastures. Voronezh.
15. YAROVENKO, V. V., M. I. SUCHALKINA, and I. S. ALIYEV. 1959. Study of soil cultivation of slopes. Sb. nauchn. rabot. NIISKh tsentral'no-chernozemn. polosy im. V. V. Dokuchayeva. Voronezh.

TOXICITY OF SOIL SOLUTION CONCENTRATIONS FOR GROWING COTTON

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In order for various crops to produce on saline land the salt tolerance of the crops is very important in addition to special agricultural and hydrotechnical practices. The sowing of salt tolerant seed varieties can ensure a more or less normal crop in areas where a less tolerant crop gives low yields. There are enough experiments illustrating the relationship of plants to the salinization of soil by one or the other salt, but there are still no definite indications of the maximum allowable salinity, even for the major crops (18, 11, 14, 8, 15, 17, 1, 10, 3, 4, 5, 7, 9, 16). The limits of salinity are usually expressed in percentages of the total amount of water-soluble salts, or of the chloride ion alone, in the weight of absolutely dry soil.

L. P. Rozov (1936) suggested the following gradations in salt content. Land with a salinity of 0.1%-0.2% can be considered as non-saline. All agricultural crops may successfully be grown on it. Land containing more than 0.5% salts is saline. It is difficult to grow crops on it and the yields are low. With intermediate salinity (0.2%-0.5%), soils give intermediate yields. Higher yields may be obtained on such soils by growing only salt tolerant crops.

The allowable salt content in soils at which various crops may be grown has been established more accurately by more recent investigations. Kovka and Mamayeva (18), who studied the salt-resistance of cotton in the Golodnaya steppe, give the following salt toxicity limits in soils.

	Salt content in the soil, %
Cotton does not germinate	1.3-1.5
Cotton germinates but is depressed	0.4-0.8
Cotton germinates and develops well	0.06-0.08

A number of experiment stations studied the salt-tolerance of crops, including cotton, in Central Asia. The Vakhsh experimental-melioration station came to the following conclusions:

	Chloride ion content in the soil, %
Cotton develops normally	0.02-0.05
Cotton is depressed	0.1-0.25
Cotton dies	More than 0.25

The effect of salts on plants manifests itself in the very early stages of their development, beginning with the swelling and germination of the seeds. Seeds germinate considerably more slowly in saline solutions than in fresh water. Germination requires, in addition to other conditions, a certain amount of moisture. The increase in the amount of water in the seeds is due to the swelling of protein colloids and also to osmosis resulting from the attraction of water by substances dissolved in the cell sap. Osmotic pressure in the soil solution can be higher that the osmotic pressure of the cell sap, and in this case there is no swelling and, consequently, the seeds do not germinate. Germination is slowed down as the salt solution concentration increases.

The salt-tolerance of agricultural crops increases with their age. The harmful effect of salts on plant depends to a great extent on soil moisture, since the concentration of the soil solution changes with changing moisture content.

When analyzing salt-tolerance we must consider both the biological peculiarities and the dynamics of development of the plant, as well as soil conditions. The biological factors determining salt-tolerance include plant species, its phase of development, and the type of root system. The soil factors include the degree and nature of salinity and soil moisture. Nevertheless, some experiments did not take into account the phase of plant development, while others did not consider soil moisture. This resulted in controversial conclusions on the salt-tolerance of one and the same crops. Evidently, crops will better endure salinity with a high soil moisture content. This indicates that we must express salt-tolerance not by the percentual content of salts in the soil, but by the concentration of the soil solution. With the same salt content in the soil, an increase in moisture promotes better development of plants, since the limit of harmful salt content in it increases (19, 2, 13, 20, 12, 6). A water extract cannot give the full picture of the composition of the soil solution, since during its preparation readily-soluble and part of the moderately-soluble salts are removed from it. Because of this the total amount of salts in the water extract is higher than in the soil solution. The toxicity of salts to plants is, evidently, determined first of all by those salts which are in the dissolved state. A water extract, which also removes from the soil part of the salts in the solid phase, does not give a completely accurate picture on the limits of toxicity of salts in the soil. It cannot give an accurate picture of the soil solution, because there is never as much moisture in the soil as is created during its preparation (1:5). The composition of the water extract in saline soils is also complicated by the mutual exchange between the cations of the solution and of the adsorption complex of the soil. The direct study of soil solutions makes it possible to eliminate the foregoing shortcomings inherent to water extracts, and to study the salts which are actually contained in the soil in a dissolved state. Our long-term investigations in this direction characterize the toxicity of various concentrations of the soil solution to cotton in central Fergana, and Golodnaya steppe, and the Chardzhou oasis. We extracted soil solutions by squeezing them out with a hydraulic press in the device constructed by P. A. Kryukov. The pressure was raised to 150 kg/cm². In central Fergana we studied the salt tolerance of cotton in the Fechenko experimental field and in Stalin kolkhoz. The first site is located in the southeastern part of central Fergana, the second, in its southeastern part. The soil in these areas is represented by meadow soils of varying degrees of salinity.

The soils characteristic of the Shur-Uzyak depression in the Golodnaya steppe are moderately saline and strongly saline sierozems and solonchaks. In the Chardzhoy oasis soil is represented by meadow soils of various degrees of salinity.

We studied the salt tolerance of cotton in the southeastern part of central Fergana (Fedchenko experimental field) in field M-1, which slopes slightly to the north. There is an irrigation ditch along its southern edge and a drain 120 cm deep along the northern edge. Because of the horizontal movement of salts, part of the field neighboring on the drain is more strongly saline than that neighboring on the irrigation ditch (Fig. 1). There were three observation plots: plot 9, located 20 m from the irrigation ditch, with non-saline meadow soil; plot 8, located in the middle of the cotton field, with slightly saline meadow soil; and plot 7, located 25 m from the drain, with saline meadow soil. According to analyses of water extracts, salinity in plot 9 was of the sulfate-calcium type. At the end of summer the salt content and concentration of the soil solution increased in the root zone. The salt composition in the soil solution was sulfate-magnesian. The best cotton (Sovetskiy variety) was obtained from this plot. The yield of raw cotton in 1940 was 22 cntr/ha (Table 1).

The soil solutions in plot 8 had a sulfate-magnesium composition, too. Here cotton was lower (shrubs up to 60 cm high) and somewhat thin. The yield of raw cotton in the same year was 17 cntr/ha.

The salinity of soils and the composition of the soil solution was sulfate-magnesium in Plot 7. As a result of the high concentration of the soil solution, cotton died during germination. The foregoing data show that the best conditions for the growth of cotton were present in that part of the field which adjoined the irrigation ditch, and where, because of filtration from it, fresh water was constantly superposed on the more mineralized ground water. Even though the ground water level rose to 80-90 cm from the surface, it did not cause harmful salinization of the soil. The mineralization of the ground water was low here, not exceeding 5 g/liter during the growing period.

The salt-tolerance of cotton in the southwestern part of central Fergana (Stain kolkhoz, Buvaydin rayon) was studied in three plots with varying degrees of salinity. The salt content in the soils of these plots, as determined from water extracts and the soil solution concentration, in the middle of summer and in autumn, is given in Table 2. The most favorable conditions for the growth of cotton (Sovetskiy variety) are present in plot 1, where the concentration of the soil solution in the root zone did not exceed 16.5 g/liter during the growing period. Salinity was of the sulfate-magnesium type. Conditions for the growth of cotton were less favorable in plots 2 and 3, since the concentration of the solution in the same soil layer reached 19-29 g/liter at the end of the growing period. We did not take into account the concentration of the soil solution in the layer from 0-5 cm, where there were practically no roots during the second half of the growing period.

In the first plot the yield of raw cotton was 17.6 cntr/ha, in the second, 5.0 cntr/ha, and in the third, 1.0 cntr/ha. In order to be able to account more accurately for the change in cotton

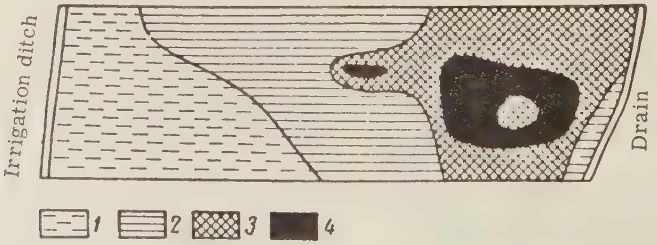

Fig. 1. - Plot M-1 of the Fedchenko experimental field. Saline areas: 1 - slightly, 2 - moderately; 3 - strongly; 4 - solonchak. Condition of cotton: 1 - good; 2 - average; 3 - depressed, 4 - bare spots.

Table 1

Analytical data on soils in the Fedchenko experimental field, 1940. Analyzed by T. A. Gevel'son

Plot No. and soil	Depth, cm	May 28			August 13			May 28			August 13		
		Dry residue, %	Content, %		Dry residue, %	Content, %		Solution concentr. g/liter			Solution concentr. g/liter	Content, %	
			Cl	SO_4		Cl	SO_4		Cl	SO_4		Cl	SO_4
		Salt content in the soils according to water extracts						Composition of soil solution					
9. Non-saline meadow soil	0—2	0,73	1,65	45,40	1,67	7,47	41,02	6,44	11,41	36,02	9,89	6,12	41,08
	2—12	0,41	1,28	43,29	0,94	1,56	46,26	7,68	3,65	44,82	8,20	3,36	44,45
	12—25	0,55	0,55	45,73	0,85	0,57	47,20	8,90	3,04	45,85	13,78	7,30	41,19
8. Slightly saline meadow soil	0—2	—	—	—	—	—	—	5,25	—	—	14,25	—	—
	2—12	—	—	—	—	—	—	6,80	—	—	15,26	—	—
	12—25	—	—	—	—	—	—	6,84	—	—	17,51	—	—
7. Saline meadow soil	0—2	5,62	5,83	43,25	8,61	1,10	48,36	34,86	4,43	45,00	123,96	3,55	45,88
	2—12	2,52	2,78	46,10	2,31	0,44	48,42	66,26	4,25	45,30	35,16	2,97	45,88
	12—25	2,29	2,53	46, 0	1,73	0,39	48,17	37,44	4,30	44,81	35,72	3,89	45,11

Note: Comma represents decimal point.

Table 2

Analytical data on soils in the Stalin kolkhoz, 1960

Plot No. and soil	Depth, cm	July 6			September 5			July 6			September 5		
		Dry residue, %	Content, %		Dry residue %	Content, %		Solution concentr. g/liter	Content, %		Solution concentr. g/liter	Content, %	
			Cl	SO_4		Cl	SO_4		Cl	SO_4		Cl	SO_4
		Salt content in the soils according to water extracts						Composition of soil solution					
1. Moderately saline meadow soil	0—5	1,20	0,93	48,15	1,27	1,70	47,44	15,12	2,38	46,36	7,94	7,87	40,38
	5—10	1,18	0,87	48,05	0,83	1,20	47,24	12,83	2,81	45,48	13,74	2,65	46,07
	10—20	1,12	0,76	47,95	0,61	1,63	46,08	16,51	2,14	46,55	15,00	2,20	46,35
	20—40	0,53	1,21	46,43	0,82	1,03	47,43	7,33	1,37	47,08	9,79	1,58	46,70
2. Strongly saline meadow soil	0—5	1,87	9,15	40,65	9,16	21,48	28,41	33,56	2,23	46,64	290,46	2,92	46,76
	5—10	1,70	7,44	42,28	2,10	10,58	39,07	3,52	17,11	24,81	28.77	4,40	44,72
	10—20	1,60	6,29	42,89	2,10	8,51	41,18	3,09	18,11	24,14	29,37	3,16	45,81
	20—40	1,66	6,57	43,00	1,79	7,31	42,45	2,28	16,46	22,56	17,73	3,30	45,68
3. Meadow solonchak	0—5	4,13	1,93	47,89	4,59	2,18	47,34	327,95	3,10	46,51	380,37	2,90	46,79
	5—10	1,26	0,13	49,25	1,18	0,64	48,35	19,09	1,38	47,70	19 65	1,99	47,04
	10—20	0,95	0,07	49,23	1,10	0,59	48,56	11,46	1,23	47,08	9,85	1,81	45,84
	20—40	1,13	0,14	49,28	1,29	0,37	48,85	7,28	1,06	47,70	7,27	1,56	45,13

Note: Comma represents decimal point.

yield, we selected three areas of 25 m² in the foregoing plots, where we assessed all the cotton shrubs, measured their heights, calculated the number of bolls, observed the rate of their opening, and harvested the raw cotton.

Calculations showed that in the plot with moderately saline soil there were 235 more cotton shrubs. As salinity increased their number decreased to 224 and 112. The average height of the cotton shrubs in the first plot was 63 cm, that in the second, 43 cm, and that in the third, 24 cm. The number of bolls was 1267, 530, and 64, respectively. Cotton ripened considerably earlier on slightly saline soil. The yield and weight of one boll was higher in the least saline soil. For instance, during the cotton harvest on September 8, 1950, the weight of one boll on moderately saline soil was 6. 9 g on strongly saline soil, 5. 3 g, and on solonchak, 3. 0 g.

There are no slightly saline soils in the Shur-Uzyak depression of the Golodnaya steppe in the area of the Zolotaya Orda railroad station. Soil is represented here by moderately saline soil, solonchak sierozem, and solonchaks. The growth of cotton (Sovetskiy varieties) begins to slow down in the second part of the summer on moderately saline sierozems as a result of the increasing salinity of these soils. On solonchak sierozems cotton becomes depressed as early as at the beginning of summer and most often dies in the germination stage.

The salt content in the soils studied, as determined from water extracts and the concentration of the soil solution in spring and autumn, is presented in Table 3.

The high concentration of the soil solution in the surface layer had apparently no substantial effect on the cotton, since there were no roots in this horizon. In the second half of summer the main mass of the roots was concentrated at a depth of 35-50 cm. The root system of cotton withdrew, so to speak, from the excess of water-soluble salts in the upper part of the soil profile as salinity increased in the upper soil horizons, and plant nutrition was achieved from the less saline lower soil horizons. The yield of raw cotton in the plot with moderately saline sierozem was 14 cntr/ha in 1941. There was no yield on colonchak sierozem, since the concentration of the soil solution in the layers from 0-5 cm and 5-10 cm was 173-39 g/liter in spring and cotton died during the germination period.

The salt-tolerance of long-fiber cotton in the Chardzhou oasis (Chardzhou experimental field) was studied in three plots of varying degrees of salinity. The salt content in the soils studied, as determined from water extracts and the concentration of the soil solution, is given in Table 4.

The concentration of the solution in the root zone of slightly saline meadow soil (except for the 0-5 cm horizon) was 12-14 g/liter in autumn. The raw cotton yield here was 19.0 cntr/ha in 1942. Cotton was depressed in the plot with moderately saline meadow soil, where the concentration of the solution

Table 3

Analytical data for soils in Frunze kolkhoz. Golodnaya steppe, 1941

Plot No. and soil	Depth, cm	May 26			October 10			May 26			October 10		
		Dry residue, %	content, %		Dry residue, %	Content, %		Solution concentr. g/liter	Content, %		Solution concentr. g/liter	Content, %	
			Cl	SO_4		Cl	SO_4		Cl	SO_4		Cl	SO_4
	Salt content in the soils according to water extracts							Composition of soil solution					
2. Moderately saline sierozem	0—5	0,91	4,21	43,82	3,46	15,87	33,53	15,78	25,41	22.59	150,98	22,04	26,94
	5—10	0,45	2,58	43,11	1,40	7,58	41,19	6,72	8.01	38.80	30,22	17.69	29,04
	10—20	0,58	2,74	44,20	1,27	5 78	42,95	7,05	8,53	39,73	26.02	12,67	35,90
	20—40	0,56	4,82	42,33	1,20	4,44	44,40	7,76	12,88	35,45	19,02	12,60	36,35
1. Solonchak sierozem	0—5	2,80	8,10	41,26	6,53	13,64	35,75	173,32	19,80	29,86	275,36	21,88	26,86
	5—10	2,06	4,35	44,80	2,00	9,19	39,94	39,16	16,34	32,00	54,72	21,07	25,90
	10—20	1,51	2,87	46,39	1,80	5,15	43,76	19,51	14,10	34,00	36,44	14,09	34,56
	20—40	1,57	2,22	47,15	1,09	4,79	43,79	19,62	13,09	36,29	21,58	12,04	36,32

Note: Comma represents decimal point.

Table 4

Analaytical data for soils of Chardzhou experimental field

Plot No. and soil	Depth, cm	September 14, 1942			March 17, 1943			September 14, 1942			March 17, 1943		
		Content, %	Dry residue, %		Content, %	Dry residue, %		Solution concentr. g/liter	Dry residue, %		Solution concentr. g/liter	Dry residue, %	
			Cl	SO_4		Cl	SO_4		Cl	SO_4		Cl	SO_4
		Salt content in the soils according to water extracts						Composition of soil solution					
1. Slightly saline meadow soil	0—0	0,78	14,24	32,80	0,18	8,59	23,53	22,36	41,06	8,43	4,31	11,96	35,70
	5—10	0,52	14,49	31,43	0,24	12,54	26,96	13,76	35,20	14,14	6,21	19,67	28,02
	10—20	0,47	17,35	28,73	0,30	15,47	28,33	14,35	36,68	13,00	7,62	23,70	24,49
	20—40	0,48	15,78	30,72	0,33	15,61	28,87	12,95	35,30	13,95	8,57	27,26	21,03
3. Moderately saline meadow soil	0—5	2,21	20,04	29,45	0,30	7,07	36,19	79,33	44,00	5,72	6,27	13,19	34,07
	5—10	1,16	6,24	43,08	0,49	12,88	33,43	16,58	29,83	19,34	11,12	22,33	25,88
	10—20	0,99	6,09	42,99	0,60	10,04	37,37	14,52	27,95	21,17	11,29	22,02	26,40
	20—40	0,89	5,62	43,57	0,72	8,95	38,95	13,16	27,14	21,99	12,18	23,90	24,34
4. Meadow solonchak	0—5	4,10	26,58	23,07	0,31	12,41	30,72	204,86	34,79	15,27	7,51	19,88	28,39
	5—10	2,41	25,19	24,38	0,97	8,30	39,95	88,91	41,19	8,54	11,46	25,21	23,62
	10—20	1,27	23,14	25,93	1,14	13,31	35,51	50,11	42,32	7,22	20,57	32,14	16,95
	20—40	1,52	7,98	41,34	1,31	12,42	36,76	22,22	32,78	16,52	24,12	32,92	16,34

Note: Comma represents decimal point.

in the roots zone was 13-16 g/liter in autumn. The yield of raw cotton here was 9 cntr/ha in 1942.

There was no yield from meadow solonchak. The concentration of the soil solution in the layers from 0-5 cm, 5-10 cm, and 10-20 cm reaches 204.8-88.9-50.1 g/liter respectively in the autumn of 1942. Cotton died here during the germination period.

Conclusions

1. Judging from the data obtained during the study of soil solutions, cotton shoots do not die at soil solution concentrations not exceeding 6-7 g/liter.

2. Normal plant development requires that the total salt concentration in the soil solution from the root zone do not exceed 15-17 g/liter with sulfatic salinization, and 12-14 g/liter with chloride-sulfate salinization.

Received March 3, 1961

BIBLIOGRAPHY

1. BURYGIN, V. V. 1942. Certain characteristics of the behavior of American cotton on the saline soils of the Golodnaya steppe and methods of increasing its salt-tolerance. Tr. Uzbeksk. fil. Akad. Nauk SSSR. No. 5.

2. VILENSKIY, D. G. 1950. Soil science.

3. GENKEL', P. A., S. S. KOLOTOVA, and V. A. NOVIKOV. 1942. Increasing the salt-tolerance of cotton on saline soils by treating the seeds before sowing. Tashkent.

4. GENKEL', P. A. 1954. Salt-tolerance of plants and methods of controlling its increase. Izd. Akad. Nauk SSSR.

5. GENKEL', P. A. 1960. Increase in the salt-tolerance of plants during the salinization of soils with sulfates. Izv. Akad. Nauk SSSR, ser. biol. No. 4.

6. GERASIMOV, I. P. and M. A. GLAZOVSKAYA. 1960. Principles of soil science and soil geography.

7. KOVDA, V. A. 1937. Solonchaks and solonetzes.

8. KOVDA, V. A. and L. YA. MAMAYEVA. 1939. Limits of salt toxicity of soils in Pakhta-Aral (Golodnaya steppe) for alfalfa and cotton. Pochvovedeniye, No. 4.

9. KOVDA, V. A. 1947. Origin and regime of saline soils. Part II.

10. NOVIKOV, V. A. 1942. Investigations of the soil-tolerance of cotton. Tr. Uzbeksk fil. Akad. Nauk SSSR. No. 5.

11. PANKRAT'YEVA-GLAGOLEVA, A. F. 1932. Development of cotton in solutions with a

high salt concentration. Tashkent.

12. PLYUSNIN, I. I. 1960. Meliorative soil science.

13. RODE, A. A. 1955. Soil Science.

14. RYZHENKOVA, M. T. 1932. Problem of the salt-tolerance of cotton. Khimiz. Sots. zemledeliya. No. 8.

15. SPENGLER, V. V. 1940. Problem of the influence of various degrees of salinity on the development and yield of cotton. Vestn. s.-kh. nauki. No. 1.

16. STROGONOV, B. P. 1949. Physiology of salt-tolerant cotton. Izd. Akad. Nauk SSSR.

17. TUYEVA, O. F. and P. G. MARSAKOVA. 1941. Rate of development and structure of the cotton harvest at varying soil salinities. Probl. sov. pochvov. Sb. 13.

18. TULAYKOV, N. M. 1912. Plants and salts in the soil. Zh. opytn. agron. Vol. 13.

19. TYURIN, I. V. 1933. Course in soil science.

20. SHAKHOV, A. A. 1956. Salt-tolerance of plants.

RELATIVE SUITABILITY OF SOILS IN THE VOLGA-AKHTUBA FLOOD PLAIN AND THE VOLGA DELTA FOR GROWING FRUIT CROPS

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The first detailed description and classification of soils in the Volga-Akhtuba flood plain and the Volga delta were published by Plyusnin (18). Later investigations on the origin and development of soil and soil material in this region, as well as the results of studies on the nutrient regime, water-physical and chemical properties, and hydrogeological conditions, published in the papers of Letunov (14), Plyusnin (19), Mikhaylov (15), Mikhaylov and Gidrov (16) Krasnova (10, 11), Kuzin (12), Kovda (9), Vladchenskih (2-5), Solov'yev (22), Chetverikova (23), Lavrent'yev (13), Yevdokimova and Korneyeva (8), Popov (20, 21), and others formed the basis for the agricultural and meliorative evaluation of the land resources of the Volga-Akhtuba region.

From 1952-1957 the Stalingrad Experimental Strain-Testing Station studied the influence of various soils of this region on the growth and productivity of fruit crops. The project of utilizing the water and land resources of the flood plain and the delta, set up by the southern state Institute for the Planning of the Water Economy (1959), calls for an increase of the area under orchards and vineyards in kolkhozes and sovkhozes of up to 36,700 hectares (almost 5 times more than in 1960). This will comprise 17% of the plowland. The studies of Pekhoto (17) and Bisti (1) served as a basis of evaluating the reaction of apple trees on soil conditions, but they did not include all the varieties of soils in the flood plain and the delta and were insufficient for judging the suitability of various soils for large-scale fruit crop orchards. The studies of the Stalingrad Station were conducted by means of a complex soil-biological investigation of orchards according to the method of Shitt (24, 25). The history and growing conditions of each orchard were studied in detail. Experimental areas were selected on the basis of planting evaluation where the growth and development of fruit trees, taken as standards, were studied. Soil profiles 2 m deep were made in the same areas by the modified method of Oskamp (27, 7). The morphological structure and water permeability of the soil were studied in these profiles, soil samples were taken for chemical and physical analyses, and the distribution of roots by horizons and layers was recorded. In some cases the characteristics of the parent material were studied to a depth of 4 m by boring at the bottom of the profiles. The horizontal distribution of roots was studied by the method of curved profiles (7). Hundred and forty orchard plots were studied in 36 kolkhozes and sovkhozes in the Central Akhtuba Lenin, Chernoyarsk, Vladimir, Sasykol', Kharabalin, Narimanov, Ikryanin, Travin, and Kamyzyak rayons. The investigations covered 2500 hectares out of 5130 hectares of orchards occupying the kolkhozes and sovkhozes of the flood plain and delta in 1952. More than 340 profiles were made, not counting borings, and about 1400 soil samples were taken, the majority of which was subject to analysis.[1]

In the present paper we will use the soil classification adopted by the Southern State Institute for the Planning of the Water Economy (20), but will separate flood plain soils from the delta soils, since they differ in the nature of the alluvium, the degree and type of salinity, the level of mineralized ground water, the reaction of the soil solution, etc. The following subgroups of soils were found in the orchards studied.

Soils of Hydromorphic series

1. Alluvial primitive-meadow soils — a) flood-plain, b) delta. 2. Alluvial meadow soils — a) flood-plain, b) delta. 3. Forest-meadow soils. 4. Dark-colored meadow soils — a) flood-plain, b) delta. 5. Dark-colored compact meadow soils. 6. Wet-meadow soils (stratified) — a) flood-plain, b) delta. 7. Dark-colored wet-meadow soils — a) flood-plain, b) delta.

Soils of the Desert-Steppe Series

Light-brown soils of Baer knolls.

Considering the size of the articles, we

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[1] Besides the author of the present article, who was the supervisor, the investigations were made with the collaboration of G.A. Selesnev (1953-1956) and P.G. Popov (1952). The soils were analyzed by G.A. Seleznev, V.M. Glukhova, and M.K. Degtyareva. From 1958-1961 the author conducted additional field investigations in the flood plain and in the delta.

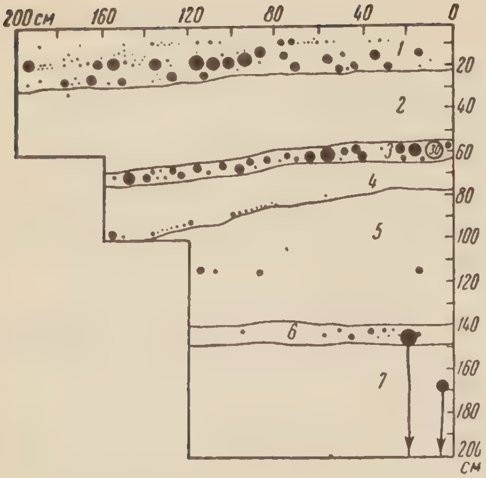

Fig. 1. - Division of the root system in stories in alluvial primitive-meadow soil. Rastun'ya cherry 13 years old. Profile 337. Kirov kolkhoz, Central Akhtuba rayon. On the side of the Akhtuba River.

1 - pale yellow-gray coarse clay loam; 2 - friable sand; 3 - gray granular clay loam; 4 - compact sand; 5 - friable sand; 6 - granular clay loam with sandy loam spots; 7 - friable sand. Dots and circles -- cross-section of roots; arrows -- direction of the roots; numbers in the circles -- diameter of the largest roots, mm. Distance from trunk, 100 cm.

decided to concentrate our attention on the description of the main soil factors affecting the growth of fruit trees, eliminating the tubular material on the indices of tree growth and development and data on the chemical and physical properties of the soils. Some information on the state of the orchards on various soils and basic analytical data for these soils are given in Table 1, which is an illustration of the generalizations made below.

Alluvial primitive-meadow soils are the youngest, most coarse-textured soils and have the least water capacity and the least amount of humus (Table 1). These soils are less suitable for orchards than the older alluvial-meadow soils. With good irrigation, trees grow and produce normally an alluvial primitive-meadow soils, but when irrigation is diminished or stopped the trees age and become unproductive more rapidly than on alluvial-meadow soils. Grapes and cherries are somewhat more stable.

The root system of fruit trees is grouped into stories by clay loam and silted layers which are located at various depths in the profile of alluvial primitive-meadow soils (Fig. 1). In each story the roots concentrate in the layer with the highest water capacity and in the overlying layer of sandy loam or stratified sand. The depth of the root story increases in layers with a weakened filtration capacity, less so in sandy material and more so if the overlying layer consists of sandy loam or thin-layered sand. In addition to continuous layers of varying thickness, sandy loam and sandy layers often contain clearly defined micro-layers in the form of lenses 1-3 mm thick, which are common to flood-plain deposits. In well-drained alluvial primitive-meadow soils (Fig. 2), poor in humus, continuous and lens-like micro-layers play an important role. Being somewhat compact and at the same time porous or granular, they retain large amounts of moisture, humus, and a sufficient amount of air. They also prevent the neighboring layers from drying.

There are several varieties of alluvial primitive-meadow soils, which are found in more depressed relief. They are underlain by clay deposits and are periodically excessively wet. This leads to an increase of the amount of rust spots in the profile and the formation of iron-manganese compounds in the form of black-brown spots and specks. Such varieties promote a better growth of fruit trees, especially apples.

The behavior of fruit trees on alluvial primitive-meadow soils depends on whether the areas are diked or not. Innundations increase the fertility of these soils, while a consistent lowering of the ground water table decreases it considerably. Alluvial primitive-meadow soils have the lowest adsorption capacity of all the soils in the flood plain and in the delta (Table 1). This must be considered when using mineral fertilizers. The content of available forms of phosphorus and potassium is considerable in spite of the low humus content.

Alluvial primitive-meadow soils of the delta differ from similar soils in the northern part of the Volga-Akhtuba flood plain and considerably less from the southern part by their greater content and higher ground water level (18). This is, apparently, the reason for the decreasing difference in the condition of fruit trees on alluvial primitive-meadow soils and alluvial-meadow soils in the direction from the Central Akhtuba to its lower reaches.

Alluvial-meadow soils are very fertile and are, together with forest-meadow soils, best for cherries and other fruit trees (Table 2).

Alluvial-meadow soils are found in the Volga-Akhtuba flood plain in the central, stratified flood plain and in slough along the river. While in the delta they are found along the river plain. They form on riverbed type deposits, but their location in lower areas than where alluvial primitive-meadow soils are found, and their distance from the main riverbed explain their somewhat higher clay content (Table 1). But the main difference between alluvial-meadow soils and alluvial primitive-meadow soils lies in the greater age of the former and the greater influence of meadow vegetation on them, as a result of which these soils are richer in humus (Table 1). Humus horizons are found at various depths in the profile and are interrupted by alluvium which is hardly touched by soil-forming processes.

The difference between individual layers in the profile of alluvial-meadow soils in the amount

Table 1

Basic analytical data for certain soils in orchards of the Volga-Akhtuba flood plain and Volga River delta

Profile No.	Soil, site of the profile, condition of trees	Depth, cm	% content of particle diam.		pH	Water extract			Humus	Available		Sum of adsorbed cations, meq	Gr. water during low-water per.	
			<0,001	<0,01		Solid res. %	meq			P_2O_5	K_2O		Level 1	Salt, %
							Cl^-	$SO_4^=$		mg/100 g				
58	Flood-plain alluvial primitive-meadow sandy loam. Central Akhtuba rayon, "Zavoyevaniye oktyabrya" kolkhoz. Along the river flood plain of the Akhtuba River. Cherry, 10 yrs. old. Good condition.	6—16	8,41	20,09	7,2	0,155	0,60	None	0,47	25,0	13,8	27,30	5—6	—
		95—100	8.80	18,60	7,4	0,120	0,18	"	0,45	—	—	—		
		105—111	13,18	32,12	7,4	0,071	0,20	"	1,02	12,5	14,4	—		
		144—154	9,00	18,85	7,3	0,087	0,16	"	0,14	12,5	10,8	21,90		
166	Flood-plain alluvial-meadow sandy loam. Kharabali, "Rossiya" kolkhoz. Apple orchard, 103 years old, near the channel of the Ashuluk stream. Good growth, good productivity.	10—20	15,11	21,89	7,2	0,129	0,23	Trace	1,84	—	—	—	4	—
		30—41	1,39	12,86	—	0,101	0.17	"	—	25,0	24,4	25,23		
		72—82	17,30	22,67	7,4	0,192	0,17	1,27	1,74	12,5	60,0	35,31		
		110—120	8,58	15,95	7,4	0,097	0,15	Trace	0,30	25,0	22,6	—		
		143—152	6,86	18,22	7,4	0,081	0,17	"	0,52	—	—	—		
271	Delta alluvial-meadow clay loam. Narimanov rayon, "Shest' pavshikh kommunarov" kolkhoz. Quince near the Bolda stream, 20-25 years old.	11—21	10,69	37,95	7,2	0,309	4.26	Trace	2,79	—	—	—	3—4	—
		26—36	9.19	36.21	7,6	0,130	0,30	"	0,71	—	—	—		
		46—56	1,23	17,83	7,4	0.082	0,20	None	2,37	—	—	—		
		110—120	1,44	19,34	7,6	0,089	0,28	"	1,16	20,0	3,8	22,89		
		170—180	13,78	33,50	7,6	0,180	0,61	0,47	1,69	—	—	—		
311	Flood-plain alluvial-meadow clay loam over buried granular soil. Stalingrad Experimental Strain-Testing Station, compartment 1. Ridge along the river flood plain. Apple trees 20 years old. Cond. excel. Prod. 12-15 mt/ha	18—28	21,22	37.6	6,8	0,315	0,32	2,28	3,81	10,0	4,8	—	5—6	—
		41—51	18,25	35,13	6.8	0,258	0,37	2,27	1.07	15,0	15.8	—		
		84—94	2,42	3,22	6,8	0,260	0.30	2,64	0,82	15,0	6,0	—		
		145—155	24,78	49,01	7,0	0,273	0,84	2,18	2,39	10.0	4,8	—		
		188—198	23,08	47,27	7,0	0,250	0,62	2,31	1,08	15,5	24,0	—		
272	Delta alluvial-meadow clay loam on buried granular soil. Narimanov rayon, "Shest' pavshikh kommunarov" kolkhoz. Along the river plain. Quince orchard, 22 years old. Strong growth, high productivity.	12—22	14,05	44.1	7,4	0,21	0,82	0,49	4,30	20,0	25,2	44,15	1,6	0,60
		30—36	13,97	44,6	7,3	0,218	1,04	0,62	4,80	—	—	—		
		67—77	1,96	7,52	7,2	0,073	0,24	Trace	0,85	—	—	—		
		101—110	10,28	42,36	7,0	0,146	0,62	"	2,18	—	—	—		
		125—135	0,97	9,77	7,1	0,193	0,61	"	1,29	—	--	—		

Table 1 con'td.

Profile No.	Soil, site of the profile, condition of trees	Depth, cm	% content of particle diam. <0.001	% content of particle diam. <0.01	pH	Water extract Solid res. %	Water extract meq Cl^-	Water extract meq $SO_4^=$	Humus	Available P_2O_5 mg/100 g	Available K_2O mg/100 g	Sum of adsorbed cations meq	Gr. water during low-water period Level 1	Gr. water during low-water period Salt, %
216	Flood-plain forest-meadow clay soil. Lenin rayon, "Volgostroy" kolkhoz. Elevated ridge in the central flood plain near the Chertovskiy slough. Hundred yrs. old pear and apple orchard. Excellent condition. Yld. up to 400 kg per tree.	5—15	39,83	71,05	5,8	0,085	0,17	Trace	10,42	25,0	38,0	—	4—5	—
		22—32	39,67	57,22	6,4	0,105	0,17	"	2,09	25,0	22,8	—		
		40—50	32.62	40,32	6,6	0,071	0,17	"	1,89	15,0	31,6	41,47		
		95—105	14,80	18,46	6,4	0,079	0,33	"	0,65	12,5	44,0	40,73		
		165—175	18,24	24,37	5,4	0,124	0,54	0,91	1,04	—	—	—		
196	Flood-plain, dark-colored, shallow meadow fine clay loam. Vladimir rayon, "Put' k kommunizmu" kolkhoz, Peschannyy Ugol village. Apple orchard 5 years old. Thined 39%. Poor growth.	9—19	28,46	46,78	6,6	0,121	0,10	Trace	2,61	25,0	33.9	44,46	3—4	—
		45—52	31,82	50,90	6,6	0,113	0,10	0,56	1,72	15,0	28,2	42,78		
		60—70	22.92	42,80	6,6	0,124	0,10	0,07	0,88	15,0	25,2	—		
		78—88	0,25	3,98	6,4	0,086	0,07	0,43	0,42	20.0	11,0	26,46		
		140—150	0,25	0,65	6,0	0,106	0,09	1,11	0,86	20,0	5,7	—		
231	Flood-plain, dark-colored thick meadow clay. Central Akhtuba rayon, "Krasnyy Oktyabr'" kolkhoz. Central flood plain. Apple orchard 15 years old. Thined 38%. Dwarfed growth, poor productivity.	3—13	26,57	75,92	—	—	—	—	—	15,0	31,6	—	3	—
		52—62	44.87	67,42	6,4	0,068	0,16	Trace	2,93	12,5	6.3	36,25		
		96—106	49,44	74,02	6.4	0,078	0,13	"	1,08	7,5	3,8	41,43		
		163—173	54,89	79,25	6,9	0,128	0,10	1,15	0,63	—	—	—		
268	Delta dark-colored medium thick meadow clay loam. Narimanov rayon, "Shestpavshikh kommunarov" kolkhoz. Island plain. Apricot. The orchard perished at the age of 5-10 years.	8—18	14,18	43.86	7,2	0.185	0,62	0,78	5,17	—	—	—	1	7,79
		22—32	12,90	38,72	7,0	0,765	0,77	7,64	—	—	—	—		
		44—54	11.18	34,40	7,2	0,101	0,61	0,06	0,95	—	—	—		
		72—82	9,23	36,43	7,0	0,219	1,69	1,17	0,46	—	—	—		
207	Flood-plain dark-colored compact meadow clay. Kapustin Yar. Lenin kolkhoz, Peschaka village. Central flood plain. Apple orchard 7 years old. Very weak growth. Depressed condition.	13—23	28,00	60,10	6,3	0,122	0,28	Trace	0,30	10.0	7,2	48,24	3	—
		41—51	57,79	77,23	6,5	0,205	0,19	0,17	3,29	8,8	6,0	52,21		
		82—92	41,19	57.32	7,0	0,121	0,21	0,21	1,70	10,0	3,6	51.82		
		110—120	9.70	19.87	6,9	0,144	0,18	0,23	0,77	10,0	3,6	31.27		
		160—170	4,13	11,68	6,8	0,111	0,21	0,18	0,80	25,0	4,5	21,07		
		220—230	1,68	3,11	6,2	0,068	0,19	Trace	0,93	20,0	4,5	—		

Table 1 cont'd.

Profile No.	Soil, site of the profile, condition of trees	Depth, cm	% content of particle diam. <0.001	% content of particle diam. <0.01	pH	Water extract: Solid res. %	Water extract: meq Cl⁻	Water extract: meq $SO_4^=$	Humus	Available P_2O_5, mg/100 g	Available K_2O, mg/100 g	Sum of adsorbed cations, meq	Gr. water during low-water per.: Level 1	Gr. water during low-water per.: Salt, %
163	Flood-plain wet meadow (Stratified) shallow coarse clay loam. Kharabali, "Rossiya" kolkhoz. Depression between ridges along the river. Cherry orchard 18 years old. Strong growth, productive trees, short-lived.	20—30	17,61	21,84	6,0	0,110	0,28	Trace	0,61	8,8	24,0	26,80	3	—
		70—80	18,21	23,59	6,8	0,109	0,17	"	0.38	8,8	17,0	29,42		
		132—142	12,12	28,72	7,0	0,075	0,30	"	0,43	—	—	—		
252	Delta wet meadow (stratified) medium thick clay loam. Narimanov rayon, "Nachalo" sovkhoz. Diked dry lake. Cherry. Strong growth. The orchard perished at the age of 13 years.	7—17	15,03	43,60	7,0	0,107	0,46	None	3,99	21,2	13,4	—	2,6	0,51
		26—36	15,86	41,09	7,0	0,093	0,46	"	3.04	16.3	6,4	—		
		70—80	2,26	8,70	7.2	0,091	0,52	"	0,43	20,0	3,8	27,90		
		119—129	26,88	57,39	7,3	0,359	4,22	Trace	3,37	12,5	6,3	56,00		
		160—170	24,13	59,70	7,3	0,174	1,15	"	1,32	25,0	9,5	46,87		

Note: Comma represents decimal point.

of nutrients and the water-aeration regime leads to irregularities in the distribution of tree roots. As a whole, the root system is strongly developed and is concentrated in sandy loam and clay loam layers. The roots are denser in the foregoing layers which contain more humus. The roots completely fill the first two meter of these soils and penetrate deeper. The roots become suddently less branched as they reach sandy layers, whereby the number of ramifications decreases as these layers thicken.

Buried soils are often found in the profile of alluvial-meadow soils, which prior to being buried develop as soils of the lake-bog type of soil formation. After having noted the practical importance of buried soils for fruit growing, Shrag (26) suggested that they be not included in the classification, even though he agreed that it was possible to record them during detailed soil investigations. The necessity of considering these soils is born out by our data. Buried soils differently affect the fertility of overlying soil layers. Buried soils are most often represented by medium or fine clay loams and contain a large amount of humus and available forms of phosphorus and potassium. They have a high water capacity, good aeration, and are not excessively drained (Table 1, Fig. 2). Those buried soils possess these properties, which have a defined granular structure and are slightly or moderately compact. Alluvial-meadow soils containing buried soils with the foregoing properties are more fertile for apples, pears, plums, and quince than those which have not these buried soils, and are somewhat less fertile for cherries. Alluvial-meadow soils overlying buried granular soils ensure the longevity of orchards, the strong growth of trees, and, most important, a long period of high productivity. Evaluation of orchards more than 50 years old showed that thinning is less and the number of diseased trees is insignificant (Table 2). The productive branches of Anis apples have the greatest longevity on these soils — 12 years (as compared to 11 years in the absence of buried soils).

The roots of fruit trees always grow in the direction where conditions are optimum (25) and concentrate in larger amounts both in the buried granular soil as well as in the neighboring layers because of the favorable nutrition and water-aeration regime (Table 3, Fig. 3). This occurs in all the orchards of the flood plain. The depth of the roots protects them from drying, freezing, and injury during soil cultivation.

In the presence of buried granular soil in the depth of the profile, the root system becomes more compact and branches out more intensely. The average density of the roots formed, i. e., their amount per unit area, is 0.30-0.43 roots /dm^2 for apple trees on the flood-plain alluvial primitive-meadow soil and 0. 49-0. 57 roots/dm^2 on alluvial-meadow soil over buried granular soil.

The productivity of alluvial-meadow soils for fruit trees decreases when these soil lie on dense, compact buried soil with a fine clay loam or clay texture. In this case the development of the root system is inhibited because of the poor aeration of the lower layers, insufficient drainage, and a poor phosphorus-potassium regime. Such soils were found only

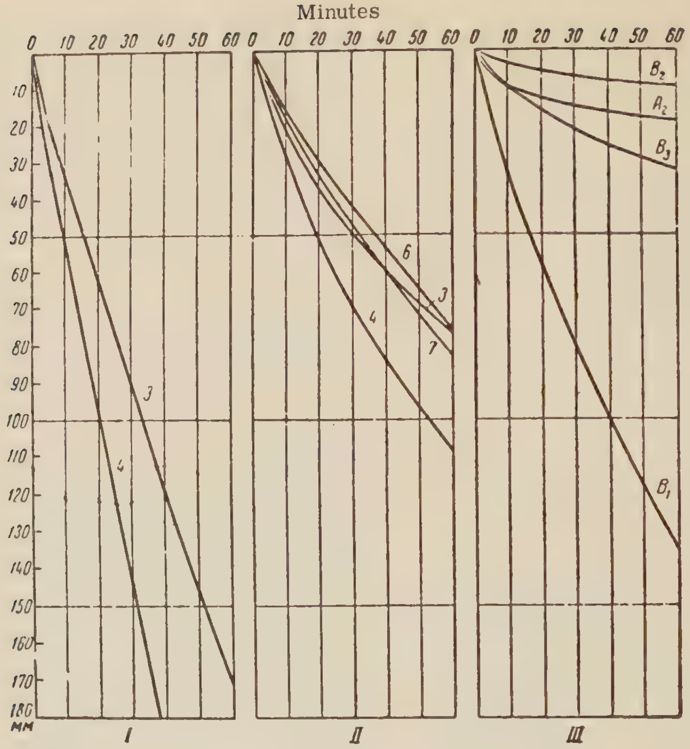

Fig. 2. - Water-permeability of certain soils in the orchards of the Volga-Akhtuba flood plain.
I. Alluvial primitive-meadow soil, Profile 337. Kirov kolkhoz, Central Akhtuba rayon. Along the Akhtuba River. 3 - layers of gray, granular clay loam (55-63). 4 - compact sand (63.77 cm). II. Alluvial-meadow soil on buried granular soil, Profile 339. Kirov kilkhoz, Central Akhtuba rayon. Ilovatyy slough along the river. 3 - light-gray granular clay loam (23-60 cm); 4 - pale yellow-gray coarse clay loam (60-79 cm); 6 - humic granular clay loam (60-79 cm); 6 - humic granular clay loam (97-115 cm); 7 - pale yellow-gray sandy loam (115-149 cm). III. Dark-colored meadow soil, Profile 334. "Lebyazh'ya Polyana" sovkhoz, compartment 3. Central flood plain. A_2 - gray fine clay loam (16.25 cm); B_1 - granular, fissured clay loam (25-68 cm); B_2 - gleyed sticky clay (68-130 cm); B_3 - same as B_2 - same as B_2 with carbonates and gypsum veins (130-180 cm).

in orchards in the flood plain.

The alluvial-meadow soils of the delta differ from the same soils in the flood plain by a higher ground water level, a more prolonged period of excessive wetting of the lower layers (the importance of which will be discussed below), and chemical properties. In the delta salts which are harmful to many fruit trees, concentrate very rarely in buried soils of a high water capacity and in buried humus horizons.

Forest-meadow soils are the most productive soils of the Volga-Akhtuba flood plain. Being located along the boundary of the stratified and granular flood plain, they are inundated for short periods of time and only when floods are high. These soils are characterized by good agronomic properties, such a high content of humus (in the upper horizons) and of available forms of phosphorus and potassium, a stable granular structure, a medium-or fine-textures (Table 1), medium compaction which is favorable to water and aeration regime, a high adsorption capacity, and the ease with which they can be cultivated.

Apple and pear trees are long-lived, very productive, and in certain cases bear every year (orchard of "Volgostroy" kolkhoz, Profile 216, Table 1) on forest-meadow soils. Cherry and plum trees also grow successfully and bear on these soils. The unusual longevity and

Table 2

Condition of apple trees on various soils of the Volga-Akhtuba flood plain

Soils	Age	Number of trees, %[a]				Thinning of the orchards %
		Healthy			Diseased	
		Strong	Medium	Weak		
Alluvial primitive-meadow	50	5,4	33,2	41,4	20,0	29,8
Alluvial-meadow	50—60	14,1	38,2	40,1	7,6	24,5
Alluvial-meadow on buried granular soils	50—70	20,8	40,8	31,8	6,6	25,1
Forest-meadow	30—60	25,9	43,1	23,1	7,9	
Dark-colored meadow	11—24	10,5	52,9	27,6	9,0	32,9

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[a] Average of 25 orchards compared.

Note: Comma represents decimal point.

productivity of the trees on forest-meadow soils correspond to a strongly developed root system. Conditions are favorable for roots at various depths even in fine-textured horizons because of their friability and granular (and sometimes curd-like) structure. Roots completely fill the upper 2 m of soil and soil material and many penetrate into deeper layers.

Dark-colored meadow soils are widespread in the central, granular flood plain and in the island plains of the delta. Delta soils of this subgroup differ from similar soils in the flood plain by a higher level of ground water, which is often mineralized, by their salinity (including chlorides), and by the reaction of the soil solution. However, dark-colored meadow soils in the flood plain and in the delta are similar in their physical properties. These soils become inundated annually during floods. All attempts to establish orchards on dark-colored meadow soils without protecting the areas from inundation have failed because the trees become soaked.

The major varieties of dark-colored meadow soils of the flood plain and delta, in diked areas, are unsuitable for orchards. The trees grow normally under good care the first years after planting. But later, when the roots reach beyond the limits of the planting hole, the picture changes. The trees slow down their growth, bear late, give low yields, and the plantings thin out (Table 2). This is the time when the trees begin to bear marks of decay. In this period the trees become suddenly less resistant to salt burns, to apple-tree cancer, to unfavorable wintering conditions, and to the smallest disturbances of the irrigation regime.

The major cause for the surffering of trees on dark-colored meadow soils in the flood plain and in the delta is the unfavorable water and aeration regime of these soils, especially in the subplow horizon. These soils develop primarily on flood-plain lacustrine, and bay (in the delta) deposits and belong to the lake-bog series of soil formation, except for shallow varieties (3). They are generally very compact. According to our determinations, the bulk density of the B horizon varies from 1.4-1.7 g/cm³. The high content of physical clay (up to 80%) and clay (Table 1) causes the intense swelling of the soil on irrigation, low water permeability (Fig. 2), and low porosity and drainage. As the soil dries is shrinks and deep cracks form. When this takes place the roots of the trees become compressed and often break. The formation of cracks is followed by the drying of their walls and the excretion of salts.

The unfavorable water and physical properties of dark-colored meadow soils, especially in the B horizon, inhibit root growth, in which two groups of roots are clearly distinguished. The horizontal roots do not penetrate into the lower horizons, but grow between the tree rows at a depth from 15-20 to 50-70 cm (Fig. 3). In many cases, however, the roots the planting hole with difficulty. The small group of vertical roots tries to penetrate into the lower horizons along the cracks. These roots are very bare, since their branches feed only in tongues of humus, which falls or is washed into the cracks from the A horizon during irrigation, and cannot grow into solid structural units. Their role in the feeding of the trees is unimportant.

Dark-colored meadow soils contain the largest amount of humus of all the meadow soils and have a high adsorption capacity (Table 1). There is an insufficient amount of available forms of phosphorus and potassium in compact horizons, because of poor aeration. If we consider that the density of roots in dark-colored meadow soils is lower than in the best soils of the flood plain and the delta (for apple trees it is 0.35-0. 42 roots/dm² along the vertical wall of the profile against 0.49-0.57 roots/dm² in alluvial-meadow soil of the flood plain), then it becomes clear how

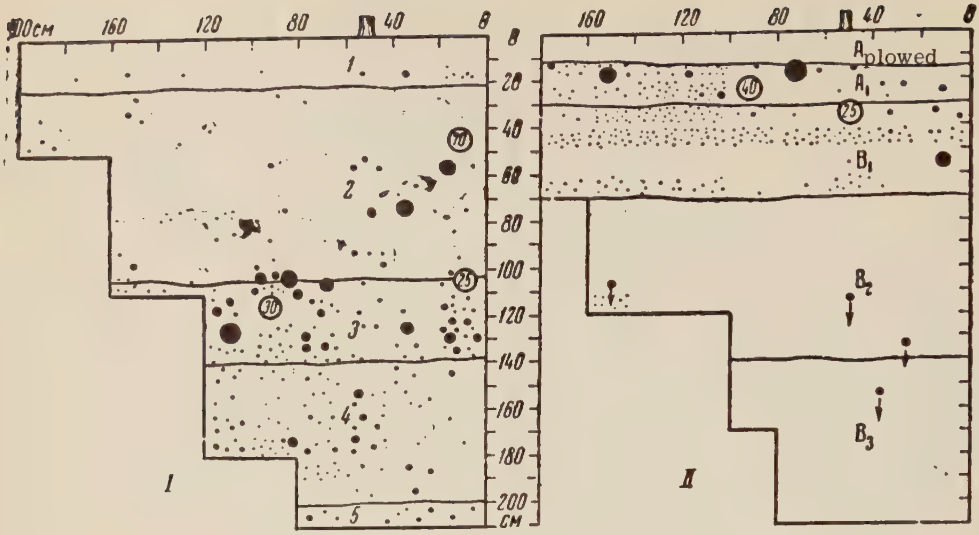

Fig. 3. - Concentration of roots of the Anis apple tree in the lower horizons of alluvial meadow soil on buried granular soil (I) and in the upper horizons of dark-colored meadow soil (II).

I. Profile 146, Kirov kolkhoz, Central Akhtuba rayon, Orlovka village. 1 - dark-gray coarse clay loam; 2 - variegated sandy loam; 3 - dark-gray clay loam; 4 - gray calcareous sandy loam; 5 - compact sand. II. Profile 54, "Lebyazh'ya Polyana" sovkhoz, compartment 3. A_{plowed} - gray, friable clay loam; A_1 - gray compact fine clay loam; B_1 - brownish-gray compact fine clay loam; B_2 - bluish-gray compact clay; B_3 - same as B_2 with a great number of carbonates and gypsum veins. Symbols the same as in Figure 1.

little of the potential fertility of these soils in use by the fruit trees.

The nutrition and water-aeration regime of dark-colored meadow soils improves after very deep plowing, but not for long. According to our observations these soils return to their initial compact state as early as the third year after plowing.

Shallow, dark-colored meadow soils, underlain at a shallow depth by sorted sand or sandy loam, are widespread in the southern portion of the Volga-Akhtuba flood plain and in the delta. Their upper horizons are compact and cracked. It is difficult to irrigate the soil when it is dry because the water penetrates into the underlying parent material along cracks. Therefore, even a small disruption of the irrigation regime, to which the fruittrees are less responsive on alluvial-meadow soils, is extremely harmful under these conditions.

Closed micro-depressions are dangerous in areas with dark-colored meadow soils because trees perish in them from the sporadic flooding by melt or rain water. Dark-colored meadow soils are unsuitable for most of the fruit trees also because of the mineralization of ground water (Table 1).

Dark-colored, compact meadow soils are completely unsuitable for fruit growing. They have extremely unfavorable water and physical properties.

Wet meadow soils (stratified) occupy the lowest relief elements of the delta and the flood plain. They are found in depressions between ridges along the river and central stratified flood plain and in the more depressed dried lakes. They are developed on coarse- and medium-textured stratified deposits (Table 1), underlain by river-bed, flood-plain, or bay (in the delta) deposits. Wet meadow (stratified) soils are similar to alluvial-meadow soils in their morphology and physical properties, but differ from them by a weak structure, high moisture content, a different degree of waterlogging, and very often by a high ground water table. The nutrient regime of these soils is related to their moisture dynamics (Table 1).

When diked, wet meadow (stratified) soils with a ground water level below 2.5-3 m are suitable for growing fruit trees, which in this case show strong growth, are very productive, but unstable, and have a low winter-resistance and are short-lived. Air drainage is insufficient in dried lake depressions. The root system of apple, cherry, and plum trees grow strongly in wet-meadow (stratified) soil, but concentrates at a depth down to 40-50 cm. Many dead roots are often found on digging. The fact that the roots do not extend much to the lower layers is attributable to the gleyzation of these layers and the prolonged standing (in some years) of ground water in them after floods. In the delta an important role is played by the salinity of the ground water, even though, according to the delta of Bisti (1), the primary role is played by

Table 3

Number of roots (2 mm and less in diameter) in various layers of flood-plain alluvial-meadow soil on buried granular soil. Profile 311. Stalingrad Experimental Strain-Testing Station, compartment 1, Anis apple trees 19 years old, excellent condition

Layer No.	Depth, cm	Characteristics of the layers	Number of roots (pieces) per 1 cm² of the vertical wall at a distance from the tree trunk (m)			
			1	2	3	4
1	0—13	Gray, friable clay loam	0,00	0,00	0,00	0,00
2	13—35	Same	1,37	1,10	0,30	0,17
3	35—60	Pale yellow-gray granular clay loam	1,00	0,50	0,15	0,05
5	62—115	Non-stratified friable sand	0,16	0,18	0,04	0,02
6	115—131	Compact sand	3,20	4,80	0,85	0,60
7	131—176	Gray, porous, fine clay loam	2,92	1,26	1,30	1,00
8	176—220	Pale yellow-gray, granular, compact clay loam	0,60	0,37	0,25	0,35

Note: Comma represents decimal point.

their level.

Dark-colored wet meadow soils of the flood plain and the delta develop on fine-textured flood-plain and bay-lacustrine deposits and occupy the most depressed relief elements. They are characterized by a higher moisture content and water-logging. Stratification is weak, even though the profile may contain sandy layers. Dark-colored wet meadow soils have a high humus content and their well-aerated upper horizon also contain available forms of phosphorus and potassium. These soils are unsuitable for apple, pear, cherry, and apricot trees and grapes because of the high ground water table and water-logging, and also because of poor physical properties.

In general, the effect of water-logging on the growth of fruit trees depends on the type of soil. Soil fertility increases along the river and central stratified flood plains which are only temporarily water-logged. This is attributable to the better moisture conditions in these soils. Therefore all fruit trees on the temporarily water-logged (periodically strongly excessively wet) soils along the river and central stratified flood plains grow better, are longer-lived and have a stronger root system which fills those sandy layers which remain root-free under less moist conditions.

Water-logging inhibits the growth of fruit trees and in this sense lowers soil productivity in the direction toward the central granular flood plain and the dry-lake area. The decrease in productivity results from a decrease in gas exchange, the deterioration of the phosphorus-potassium regime, and the accumulation of ferrous iron. The water-logging of the soils in the central granular flood plain and in the dry lakes does not seriously affect small fruits and quince. Quince grows and bears best in areas with a ground water level at 70-80 cm during the recession of floods and at 140-200 cm during the low-water period, where the water can be mineralized and unfit to drink (quince orchard in "Put' Lenina" kolkhoz, Travinsk rayon). Such hydrogeological regime is found in wet-meadow and dark-colored meadow soils, which are very valuable for growing quince. At high ground waterlevels, the root system of quince concentrates at a depth of 20-60 cm. Frosts, which occur most often in relief depressions, present no danger to quince.

All wet meadow as well as thick, dark-colored meadow soils with a high level of fresh ground water are best suited for growing berries. The danger of flooding of dry lakes by melt and rain water to strawberries must be considered.

Light-brown soils of Bear knolls are characterized by a coarse texture, slight compaction, a small amount of humus, and calcareous B and C horizons. The ground water is at a depth from 8-13 m. With good care and proper irrigation fruit trees grow and bear satisfactorily on light-brown soils, even though they are smaller and less productive than trees of the same age on the best flood-plain lands. Poor agricultural practices and decreased irrigation cause a decrease in productivity, a decrease in the quality of the fruits, rapid drying out, and the death of the trees. This is most pronounced on southern slopes for two reasons: a) the soils on southern slopes are solonetzic, and b) trees on southern slopes suffer more from overheating and sharp temperature fluctuations. Grapes are most heat-resistance and are also resistant to slightly solonetzic soil. Cherries also endure slightly solonetzic soil well, but on southern slopes they become sick with gummosis. Therefore cherries can be grown on northern slopes. But the major, most resistant tree on non-solonetzic light-brown soils on the northern slopes of Bear knolls is the apricot.

The growing of orchards and vineyards on Bear knolls is generally associated with great difficulties. The greatest danger is that of secondary salinization. Excessive irrigation or springkling may cause the irrigation water to come into contact with saline Khvalynskian deposits, which form the core of the Bear knolls, the general rise of mineralized ground water, the rise of the capillary fringe, and the salinization of soils at the bottom of the slope.

In concluding our survey of the suitability of the major soils of the flood plain and the delta, we must discuss the problems of salinity and solonetzization. In studying the orchards in certain areas of the Volga-Akhtuba flood plain we found soils with pronounced solonetzization (6). We noted that the presence of adsorbed sodium of up to 6%-8% of the total adsorbed cations does not affect the structure of soils of the meadow series along the river and central stratified flood plains, while it negatively affects the structure and physical properties of soils in the central granular flood plain, and also often in buried soils. Apple, pear, and cherry trees are non-tolerant and grow poorly on dark-colored solonetzic meadow soils. The negative effect of solonetzization decreases in moist areas, subject to temporary water-logging.

Solonetzic soils are widespread in the Volga River delta. The talus of Bear knolls, and soils in the plains between the knolls and in bay-lacustrine depressions are especially saline. Saline soils are encountered much more rarely in the Volga-Akhtuba flood plain. Soil salinity increases after diking at a distance from the river bed (13, 21). Relief elements with saline soils are accompanied in the delta by a high level of strongly mineralized ground water. The most salt-tolerant tree in these areas is the quince. With a salt content of 0.3% in the soil, including 0.04%-0.06% of chloride ion (in the absence of normal sodium and a minimum amount of sulfates), local varieties of quince grow normally and bear to the age of 25 years. Higher salt concentrations are harmful to the quince in any soil. On the whole, the salt tolerance of fruit trees under these conditions is the following in the order of decreasing tolerance: quince, pear, cherry, apple, and apricot. The salt-tolerance of apple trees is small. When the salt content in the upper meter of soil is 0.3%, including 0.03% of chloride ion or 0.08% of sulfate ion, orchards thin out considerably or die if a thick layer of fine clay loam or clay with a poor water permeability is located at a depth below 100 cm. In all other cases apple trees are non-tolerant if the concentration of chlorides and sulfates is about one third more than the foregoing values.

Conclusions

1. The most suitable soils for growing fruit crops in the Volga-Akhtuba flood plain and the Volga delta are those found in the central stratified flood plain. The suitability of soils for large-scale orchards decreases in the direction toward the river and central granular (clayey) flood plains, whereby it decreases gradually in the first case and rapidly in the second.

2. The order in which the suitability of soils in the flood plain and the delta for growing apples decreases is the following (under irrigated conditions): forest-meadow soils; alluvial-meadow soils on buried granular soils in the flood plain; alluvial-meadow soils on buried granular soils in the delta; alluvial meadow soils on buried compact soils; alluvial primitive-meadow soils; and wet-meadow (stratified) soils with a low ground water table. Dark-colored soils, dark-colored compact meadow soils, and dark-colored wet meadow soils are not suitable for growing apples. As compared to the apple, the pear grows better on more water-permeable soils and worse on excessively wet soils. The cherry grows better on the variety of alluvial-meadow soil which does not contain buried soil to a depth of 2 m.

3. Excessive wetting by flood water increases the productivity of soils of the meadow series, but decreases the productivity of soils (in relation to fruit trees) of the lake-bog series of soil formation.

4. The marketable crops must be distributed along the relief elements of the Volga-Akhtuba flood plain in the following manner: cherry and grapes along the river flood plain; apple, cherry, pear, and plum in the central stratified flood plain; and berries in the central granular flood plain and in dry lakes.

The most efficient distribution of fruit trees and grapes on the relief elements of the Volga River delta is: grapes on the southern slopes of Bear knolls and apricot and cherry on their northern slopes; quince in the plains and depressions between the knolls; grapes and cherry along river ridges; apple, pear, cherry, plum, and apricot along the river plains; and quince and berries in island plains and dried lakes.

5. In assigning land for orchards primary attention should be paid to the water and physical properties of the soil in the Volga-Akhtuba flood plain and to the salt regime, and the level and quality of ground water in the Volga River delta.

Received January 19, 1961

BIBLIOGRAPHY

1. BISTI, YE. G. 1949. Development of the root system of the apple tree in relation to the ground water and the salinity of soils in the Volga River delta. Dissertation. Michurinsk.

2. VLADYCHENSKIY, S. A. 1952. Problems of the melioration of the Volga-Akhtuba flood plain and of the delta. Vestn. MGU. Vpy. 3, No. 5.

3. VLADYCHENSKIY, S. A. 1954. Genesis of soils in the Volga-Akhtuba flood plain and the delta. Pochvovedeniye, No. 9.

4. VLADYCHENSKIY, S. A. 1955. Soil-meliorative characterization of the Volga-Akhtuba flood plain and of the Volga delta. Dissertation. MGU.

5. VLADYCHENSKIY, S. A. 1958. Water-physical properties of soils in the Volga-Akhtuba flood plain and in the Volga delta and their changes depending on the soil formation process. In the book: Soil-melioration investigations in the Volga-Akhtuba flood plain and in the delta. MGU.

6. DEVYATOV, A. S. 1957. Solonetzic soils in the Volga-Akhtuba flood plain. Papers presented at the Scientific Conference in 1957 (Stalingrad Agricultural Institute). Vol. 1.

7. DEVYATOV, A. S. 1960. Methods of studying the root system of fruit-bearing plants. Papers presented at the Scientific Conference of 1957 (Stalingrad Agricultural Institute). Vol. 2.

8. YEVDOKIMOVA, T. I. and K. I. KORNEYEVA. 1958. Soils of the western part of the Volga delta and of dry lakes in the delta area. In the book: Soil-melioration investigations in the Volga-Akhtuba flood plain and in the Volga River delta. MGU.

9. KOVDA, V. A. 1951. Soils of the Volga River delta and their place in soil formation. Tr. Gos. okeanografich. in-ta (GOIN). Vyp. 18 (30).

10. KRASNOVA, N. G. 1951. Formation of the Volga delta deposits. Tr. GOIN. 18(30).

11. KRASNOVA, N. G. 1951. Regional description of the Volga delta. The delta proper and the dry lakes in the eastern sub-steppe. Tr. GOIN. 18 (30).

12. KUZIN, V. N. 1951. Regional description of the Volga delta. Upper part of the Volga delta. Tr. GOIN. 18 (30).

13. LAVRENT'YEV, YU. L. 1954. Water and salt regime of soils in diked areas in the western, hilly part of the Volga River delta. Author's summary of his dissertation. MGU.

14. LETUNOV, P. A. 1942. Soils of the Volga-Akhtuba flood plain and of the Volga River delta. Collection in memory of Academician V. R. Vil'yams. Izd. Akad. Nauk SSSR.

15. MIKHAYLOV, YE. YA. 1951. Explanatory note to the soil map of the Volga delta and of sub-steppe dry lakes. Tr. GOIN. 18(30).

16. MIKHAYLOV, YE. YA. and M. P. GUDKOV. 1951. Regional description of the soil of the Volga delta. Tr. GOIN. 18(30).

17. PEKHOTO, F. I. 1948. Root system of fruit-bearing plants in relation to the soil and soil material conditions in the orchards of the Lower Volga region. Dissertation. Pavlovsk.

18. PLYUSNIN, I. I. 1938. Soils of the Volga-Akhtuba flood plain. Stalingrad.

19. PLYUSNIN, I. I. 1949. Flood-plain soils. Tr. Odesskogo gos. in-ta. Vol. 7 (60). Sb. geol. f-ta. Vol. 1.

20. POPOV, A. A. 1960. Classification of flood-plain soils in the Volga-Akhtuba flood plain and the Volga River delta. Pochvovedeniye. No. 5.

21. POPOV, A. A. 1960. Change in soil-melioration conditions during the diking of the Volga-Akhtuba flood plain. Pochvovedeniye. No. 7.

22. SOLOV'YEV, P. YE. 1953. Soils of the Volga-Akhtuba flood plain in relation to the problem of their irrigation. Vestnik MGU. Vyp. 4, No. 6.

23. CHETVERKIKOVA, O. P. 1953. Development of the meadow stage of the sod soil formation process in the Volga River delta. Author's summary of her dissertation. MGU.

24. SHITT, P. G. 1930. Method and program for the biological investigation of orchards. Izd. Sadvintresta RSFSR.

25. SHITT, P. G. et al. 1937. Fruit growing in the Kursk and Voronezh Oblast's. Moscow.

26. SHRAG, V. I. 1953. Experimental classification of flood-plain soils Pochvovedeniye, No. 11.

27. OSKAMP, J., L. P. BATJER. 1932. Soils in relation to fruit growing in New York, Part 2, Cornell Univ. Agr. Exp. Sta. Bull. 550.

RIDGING FOR GROWING CORN ON SOD-PODZOLIC SOILS

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As we know, one of the characteristics of most regions of the non-chernozem zone is high moisture availability and short duration of the frost-free growing season with moderate temperatures. The principal soils of these regions are sod-podzolic medium- and fine clay loams. They have poor physical properties, warm slowly in the spring, and are susceptible to the formation of a soil crust, which inhibits uniform sprouting. They are often excessively wet during the growing period, as a result of which the aeration regime of the plowed layer is disturbed and this leads to a deterioration of the nutrient regime of agricultural plants.

As a result of the expansion of areas under corn, corn will be planted on soils with unfavorable agricultural-physical properties, which may lead to a decrease in yield.

Considering the biological peculiarities of this crop, which require fertile soils and a good aeration regime, we must develop such methods of growing it which would improve the physical properties of soils and the supply of nutrients to plants.

From this point of view, the ridging method of planting corn deserves attention. Ridges are widely used for growing vegetables and potatoes, while in the non-chernozem zone they are recommended for growing certain grain crops (20). In northern China (11) almost all crops are grown on ridges.

The ridging method of planting corn in the non-chernozem zone was used as early as in the 1860's by the director of the agricultural school in Alm-Zaten, Ostzey Government, Sintenis (17). Many investigators recommend that corn be planted on ridges (8, 16, 7) and now this method is one of the regular agricultural practices for growing this crop in certain northwestern regions.

The majority of the leading agriculturalists grow corn in ridges in addition to preparing the soil well, adding the correct amount of fertilizers, planting corn during optimum periods, and careful soil management. L. T. Bel'skaya, of the Savich sovkhoz, Gomel' Oblast' (1), has obtained extremely high corn yields (2000 cntr/ha of green mass with cobs). In addition to applying large amounts of fertilizer during the growing periods the corn plants were hilled up three times with horse-drawn ridges.

In 1957-1959 we studied the effect of ridge planting on the physical properties of soils and corn yield in the Moscow regions at the experimental farm of the Agricultural Scientific-Research Institute of the Central Regions of the Non-Chernozem Zone (Nemchinovka).

The soil in the experimental plot was sod-podzolic, medium silty clay loam.

As we can see from Table 1, the soils of the experimental plots have a low percentage of humus (1.9-2.2), are not too highly saturated with bases, and have a rather high hydrolitic acidity and an insignificant amount of mobile aluminum.

In 1958-1959, 20 metric tons/ha of manure and up to 45 kg of effective NPK per hectare were added to the corn. In 1959, 30 metric tons/ha of peat-humus compost and 90 kg of NPK per hectare were used.

A mounted KON 2.8 cultivator with ridging blades were used to make the ridges. The height of the ridges was 20 cm. The square-next sowing was used to plant corn on the ridges. During the growing period the soil between the rows was cultivated with cultivators and ridges. We studied the dynamics of temperature, moisture, available forms of nutrient elements, and the supply of air to the soil in the ridges and on the flat surface.

Soil Temperatures

According to the data of many investigators, ridges have a favorable effect on the temperature regime of the soil (6, 12, 14, 18). Soil temperatures were measured hourly 24 hours a day with Savvinov soil thermometers. Days were selected with various weather conditions; observations on the dynamics of temperature were made for 16 days. The temperature was measured in ridges of various orientations and in flat areas, mulched with 30-50 metric tons/ha of peat.

The course of daily temperatures is illustrated

Table 1

Results of chemical analysis of soil samples from the plowed layer from 0-20 cm

Year	pH of the salt extract (according to Allyamovskiy)	Hydrolytic acidity of the soil, meq (according to Kappen)	Total amt. of adsorb. bases, meq/100 g of soil	Degree of base saturation, %	Humus (according to Tyurin)	P_2O_5 (according to Kirsanov)	K (according to Peyve)	Available Al
						mg/100 g		
1957	5,5	2,99	8.46	73,9	2,21	12,5	—	None
1958	4,5	3.97	12 90	76,5	1,90	20,0	12,6	0,3
1959	5,1	3,06	10,18	76,9	1,92	17,5	15,0	0,2

Note: Comma represents decimal point.

by the curve constructed on the basis of hourly measurements from July 15-18, 1958 (Fig. 1). According to the data of the Nemchinovka agricultural-meteorological station, these days were characterized by the following weather conditions: sunshine duration according to the heliograph was 12.8 hours on July 15, 13.1 hours on July 16, 7.8 hours on July 17, and 9.7 hours on July 18. There was a weak southwesterly wind, cloudiness was medium, and the average daily air temperature was 21.0°C on July 15, 16.7°C on July 16, 17.6°C on July 17, and 21.0°C on July 18.

Soil temperature was measured at a depth from 5-15 cm. Since its trend was the same in the same experiments, we present data only for the depth of 5 cm. The average daily temperature at this depth during the period of observation was the following, depending on the experimental treatment: 1) 19.2°C with a flat surface (control); 2) 19.7°C with a flat surface, mulched with 30 metric tons/ha of peat; 3) 20.4°C in ridges oriented from north to south; and 4) 20.7°C in ridges oriented from east to west.

The positive effect of the ridges is attributable by the greater capture of direct and scattered solar radiation because of the increased surface and decreased albedox.

The higher temperature and greater warming of the ridges as compared to the flat surface is, apparently, the result of decreased heat capacity and increased thermal diffisivity of the soil in the ridges.

We can draw the following conclusions on the basis of observations on the temperature regime:

1. The ridges had a more active temperature balance as compared to the flat surface. Soil

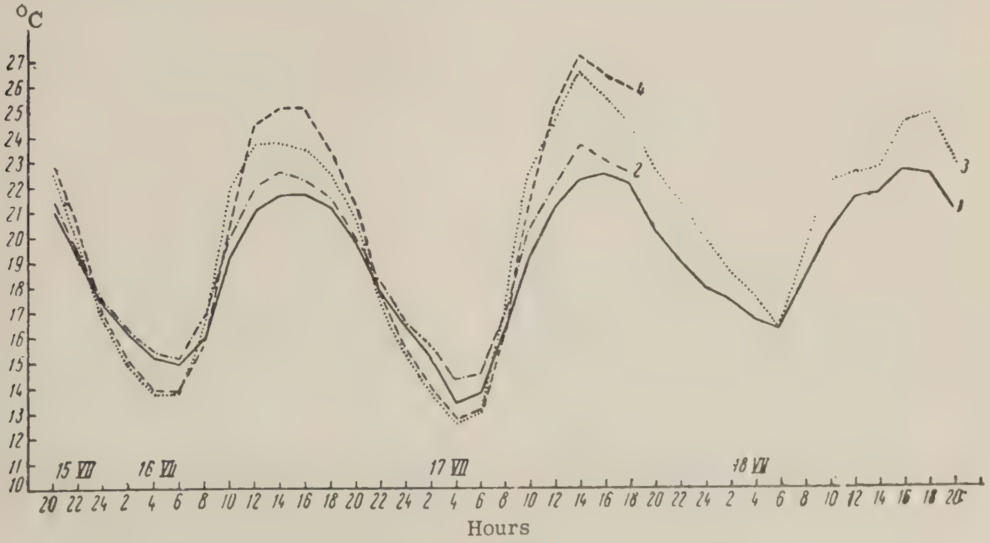

Fig. 1. - Course of daily temperature at a depth of 5 cm in the ridges and in a flat area from 8 p.m. on July 15, to 8 p.m. on July 18.
1 - flat surface; 2 - same, mulched with peat; 3 - ridges oriented from north to south; 4 - same, oriented from east to west.

temperature at a depth of 5 cm in the ridges was 3-4°C higher during the day and 1.5-1.7°C lower at night before dawn than on the flat surface. However, such decrease in temperature before dawn was observed only during nights with strong cooling and only in the upper soil layer.

As a rule, the average daily temperature was higher in the ridges than on the flat surface. The only exception were days without sunshine, with continuous cloudiness, and moderate cold wind.

2. In the non-chernozem zone with long daylight (16-17 hours), ridges increase the temperature of the plowed layer, which is very important for the increase of the effective productivity of sod-podzolic soils when growing such heat-loving crop as corn.

3. The temperature is highest during the daytime in ridges oriented from east to west, and, therefore, they must be considered the best.

4. Mulching with 30-50 metric tons/ha of peat increases the soil temperature at a depth of 5 cm during the daytime by 1.0-1.5°C, and by 0.5-1.0°C at night as compared to a flat, non-mulched surface. But mulching has not been successful in the experiments, both agriculturally and economically.

The surface layer of sod-podzolic clay loam soil is very moist. Mulch and peat reduce the evaporation of excess moisture and as a result the plowed layer warms slowly. At the same time, favorable conditions are created at the soil surface for the sprouting of weed seeds, which necessitates weed control before the sprouting of corn in the cold and long spring.

After the soil between the rows is cultivated the mulch becomes mixed with the soil and can serve no more as a means of increasing soil temperature.

Dynamics of Aeration

Because of their friable structure, ridges promote the better aeration of the plowed layer as compared to a flat surface (6, 13, 19). The structure of the plowed layer was determined by taking soil cores (6). The volume of the core sampler was 200 cm³. The cores were replicated 3-4 times.

Data on the structure of the plowed layer are presented in Table 2. As we can see from this table, the ridges had a higher degree of aeration than the flat surface. Even in the relatively dry year of 1959 the porosity of the ridges during the entire growing period exceeded 10% of total porosity. On the basis of the data obtained we may conclude that the ridges contain enough oxygen for plant roots and for oxidation reactions which take place in the soil.

Soil Moisture Dynamics

In the agricultural-climatic regionalization of the USSR according to moisture availability, the non-chernozem zone is classified as a zone of adequate and excessive moisture (3, 10, 15). However, because of the shallow plowed layer,

Table 2

Struction of the plowed layer in 1958 experiments

Indices	Experimental treatment	May			June			July			August			September		
		Depth, cm														
		0—10	10—20	20—30	0—10	10—20	20—30	0—10	10—20	20—30	0—10	10—20	20—30	0—10	10—20	20—30
Total porosity, cm³	Ridge	116,7	105,8	94,6	115,3	103,5	90,7	111,7	101,3	98,8	122,3	97,6	96,2	109,7	103,7	85,4
	Flat surface	97,9	95,1	92,8	106,8	97,5	93,6	105,0	94,8	89,6	105,4	97,3	82,3	109,4	103,5	89,1
Non-capillary porosity	Ridge	45,3	28,4	18,8	42,7	25,0	7,7	30,7	24,3	25,5	37,1	19,8	16,8	33,8	26,4	7,3
	Flat surface	28,0	15,1	19,9	23,4	11,5	14,5	25,2	15,8	12,8	20,8	14,9	7,6	35,2	22,0	11,6
Volume of air in the soil	Ridge	81,1	58,3	31,4	72,2	50,0	16,6	73,8	51,2	33,9	85,9	61,0	60,3	68,0	65,1	37,6
	Flat surface	53,4	34,9	36,9	48,9	31,3	17,3	58,9	27,9	29,7	73,6	61,2	52,5	65,9	59,1	52,7
Degree of aeration (ratio of volume of air in the soil to total porosity), %	Ridge	69,4	55,2	32,7	62,5	48,6	20,5	66,9	51,0	47,3	75,9	62,0	55,8	62,8	56,8	43,5
	Flat surface	54,3	35,8	33,6	47,4	39,4	28,9	52,7	39,7	32,7	70,6	52,9	53,7	60,1	53,3	49,7

Note: Comma represents decimal point.

sod-podzolic soils suffer at some periods both from a deficiency as well as an excess of soil moisture. Therefore, agricultural practices of growing crops in the non-chernozem zone must promote the creation of a large and stable moisture supply and control excess soil moisture during periods of ample precipitation.

Ridging successfully meets these problems as compared to ordinary planting on a flat surface (11, 13).

Because of their more friable surface layer, ridges capture precipitation. If they are oriented across a slope, they can serve as a means of controlling erosion.

Because no water stands in the ridges, no soil crust forms. This increases seed germination in the field and conserves moisture from excessive evaporation. In warm weather, the upper 5 cm of the soil in the ridges dry up rapidly, which later prevents moisture evaporation from the deeper layers (4). Our data, presented in Table 3, bear witness to the favorable water-aeration regime of ridges for plants.

During the experiments of 1958-1959 moisture was determined in percentages of absolutely dry soil samples and then reduced to millimeters of available moisture. In order to do this we determined the bulk density and the maximum hygroscopicity of the soil (by exposing the soil samples over 10% H_2SO_4). Critical moisture (wilting moisture), taken as 1.5 of maximum hygroscopicity, was deducted from the total moisture content of the soil (Table 4).

In spite of the fact that the second half of the summer of 1959 was very dry, especially the second and third decades of June and the second decade of August, the amount of available moisture in the 0-50 cm layer of soil in the ridges and on the flat surface was almost the same. The only difference was in the distribution of moisture by layers. The ridges contained less available moisture (in mm) in the upper 0-10 cm, this difference disappeared in the 10-20 cm layer, and starting with a depth of 20 cm the ridges contained more moisture than the flat surface at the same depth.

It must be noted that the pattern of soil moisture distribution is somewhat different when calculated in percentages of absolutely dry soil. This is attributable to the fact that the upper layers of the ridges have a smaller bulk density and, therefore, contain a lesser absolute amount of moisture. In sod-podzolic soil the podzolic horizon, which contains a lesser amount of available moisture begins from a depth of 20 cm.

Table 3

Soil moisture in 1957 experiments, % of absolutely dry sample

Experimental treatment	Depth, cm	Date of moisture determination			
		13.V	23.V	18.VII	5.VIII
Flat surface	0—10	18,8	16,1	16,0	21,2
	10—20	22,8	20,1	20,1	22,6
	20—30	22,1	20,7	19,5	20,1
Ridges	0—10	14,4	12,7	18,9	22,1
	10—20	22,8	23,8	22,2	22,0
	20—30	19,2	20,7	21,3	20,9

Note: Comma represents decimal point.

As we know, soil compaction has a substantial effect on the absolute moisture content in a given soil layer. As we can see from Table 4, with the same moisture content, expressed in percentages of absolutely dry soil, but with varying bulk densities, the soil will contain different absolute amounts of moisture in millimeters, i. e., the higher the bulk density (within the limits from 1.0-1.5 g/cm^3), the greater is the absolute amount of moisture. Since the absolute moisture amount is important to plants, and not the percentual expression, we must calculate the moisture in millimeters and determine the bulk density several times during the growing period, since it is subject to change, depending on soil cultivation.

Content of Available Forms of Nutrients

As a result of improved physical properties of soil, the ridges contain a larger amount of available forms of nutrients (2, 6, 13, 19). In addition, there is no significant leaching of readily-soluble nutrients in the ridges (11).

In order to study the influence of ridges on the nutrient regime of the soils, in 1957-1959 we followed the dynamics of nitrates, phosphoric acid, and potassium. Table 5 presents data for 1959 only, since similar results were obtained in the preceding years.

As we can see from Table 5, the ridges contain a larger amount of nitrates and readily-soluble phosphoric acid, and these differences increase with depth. The content of available potassium in 1959 was the same, even though in 1957 and 1958 there was somewhat more potassium in the ridges than in the flat area.

The improvement of the physical and chemical properties of soil in the ridges can also be seen in the growth of micro-organisms (Table 6).

The total amount of micro-organisms in the surface layer of the ridges and that of the flat area was the same, but starting with a depth of 10 cm their content was higher in the ridges.

The improvement of the physical properties of the soil as a result of ridging had also a considerable effect on the corn crop and on the yield of dry matter from the hectare (Table 7).

On the basis of three-year data on the ridge planting of corn on clay loam sod-podzolic soils in the Moscow Oblast', we may conclude that:

1. The ridges have a higher (by 1.5-2°C) average daily temperature than a flat surface.

2. Because of the friability of the ridges, aeration remains above 50% throughout the growing period, while non-capillary porosity exceeds 10% of total porosity, which creates a

Table 4

Amount of available moisture in mm under corn when planted on ridges and on a flat surface, 1959

Experimental treatment	Depth, cm	Max. hygroscopicity, %	Wilting moisture mm	May 11			July 1			July 19			August 5			August 24		
				Moisture, %	Bulk density, g/cm³	Avail. moisture, mm	Moisture, %	Bulk density, g/cm³	Avail. moisture, mm	Moisture, %	Bulk density, g/cm³	Avail. moisture, mm	Moisture, %	Bulk density, g/cm³	Avail. moisture, mm	Moisture, %	Bulk density, g/cm³	Avail. moisture, mm
Ridges	0—5	—	3,85	—	—	—	18,6	1,05	6,0	17,9	1,19	2,8	3,4	1,05	—	3,4	1,08	—
	5—10	—	3,85	—	—	—	21,3	1,05	6,3	20,6	1,19	8,4	8,6	1,05	0,7	7,4	1,08	0,1
	0—10	3,8	7,7	20,6	1,09	14,8	—	—	12,3	—	—	11,2	—	—	0,7	—	—	0,1
	10—20	3,8	7,7	22,8	1,34	22,8	23,6	1,20	20,6	22,0	1,33	21,6	11,0	1,21	5,6	8,1	1,34	4,2
	20—30	3,5	7,0	23,2	1,35	24,3	23,8	1,39	23,1	22,4	1,4	24,4	12,2	1,32	9,1	8,7	1,39	5,0
	30—40	3,7	8,8	22,6	1,44	23,7	20,1	1,44	20,1	20,1	1,44	21,1	12,6	1,44	9,3	9,6	1,44	4,0
	40—50	5,0	11,2	19,8	1,49	18,0	19,4	1,49	17,5	20,5	1,49	19,3	15,5	1,49	11,0	14,7	1,49	9,7
	0—50	—	—	—	—	103,6	—	—	93,6	—	—	97,6	—	—	35,7	—	—	23,0
Flat surface	0—5	—	3,85	—	—	—	21,8	1,15	8,7	18,4	1,34	8,4	3,1	1,21	—	3,2	1,26	—
	5—10	—	3,85		—	—	24,1	1,15	10,0	22,2	1,34	11,5	9,3	1,21	1,3	7,6	1,26	0,9
	0—10	3,8	7,7	21,3	1,31	20,2	—	—	18,7	—	—	19,9	—	—	1,3	—	—	0,9
	10—20	3,5	7,0	21,1	1,35	21,5	23,9	1,25	22,9	22,6	1,4	24,6	11,3	1,31	7,8	8,4	1,28	3,8
	20—30	3,7	8,8	20,3	1,38	19,2	23,0	1,32	21,6	21,4	1,4	21,2	13,3	1,44	10,4	9,6	1,35	4,2
	30—40	5,0	11,2	18,3	1,44	15,1	20,6	1,44	20,5	19,9	1,44	16,4	13,7	1,44	7,5	12,5	1,44	5,8
	40—50	6,3	14,2	16,9	1,53	11,5	20,6	1,53	17,3	19,0	1,53	14,6	15,3	1,53	9,2	16,1	1,53	9,6
	0—50	—	—	—	—	87,5	—	—	101,0	—	—	96,7	—	—	36,2	—	—	24,3

Note: Comma represents decimal point.

Table 5

Content of available forms of nutrients

Experimental treatment	Depth, cm	Date of determination						
		May 12	June 2	June 25	July 11	July 24	August 11	Sept. 11
Nitrates, mg/kg of soil								
Flat surfaces	0—20	42	73	83,0	205	155	143	126
	20—30	—	—	58,0	100	69	18	33
Ridges	0—20	103	73	89,0	255	227	211	243
	20—30	—	—	79,5	145	125	46	29
Phosphoric acid, mg/100 g, according to Kirsanov								
Flat surfaces	0—20	17,5	22,5	30,0	27,5	26,2	22,5	24,4
	20—30	—	12,5	30,0	12,5	15,0	10,0	14,0
Ridges	0—20	30,0	26,2	30,0	35,0	35,0	30,0	31,0
	20—30	—	25,0	30,0	30,0	30,0	25,0	28,0
Potassium, mg/100 g of soil, according to Peyve								
Flat surfaces	0—20	13,3	22,7	21,3	—	—	18,3	15,0
	20—30	—	13,9	16,0	—	—	20,0	10,0
Ridges	0—20	17,8	20,4	16,0	—	—	18,4	13,9
	20—30	—	25,0	16,0	—	—	16,7	11,1

Note: Comma represents decimal point.

Table 6

Development of aerobic micro-organisms on starch-ammonium agar in 1959

Experimental treatment	Depth, cm	Total content in million per g of soil		
		Date of determination		
		May 11	June 6	July 23
Ridges	0—10	7,06	7,44	11,72
	10—20	5,60	8,36	6,60
	20—30	12,96	5,04	10,55
Flat surface	0—10	7,60	8,76	5,02
	10—20	4,80	5,50	3,60
	20—30	2,73	5,00	4,16

Note: Comma represents decimal point.

Table 7

Yield of Voronezhskaya 76 variety corn, depending on method of planting

Year	Planting method	Yield, cntr/ha		
		Total mass	Including cobs	Absolutely dry matter
1957	Ridging	256	115	47
	Ordinary	192	88	34
1958	Ridging	293	85	51
	Ordinary	228	68	37
1959	Ridging	254	103	67
	Ordinary	244	94	58

favorable hydrogen regime in the soil.

3. Corn plantings on ridges have a sufficient supply of available moisture. The upper 0-10 cm layer contains somewhat less moisture, but in the layer from 0-50 cm in the ridges there is the same amount of moisture, or slightly more than in soil with a flat surface.

4. Because of the improved physical properties of soil in the ridges, micro-biological activity is increased and the content of available nutrients, such as nitrates, phosphoric acid, and in some cases, potassium also increases.

5. As a result of the improved temperature and aeration regime, corn can be planted somewhat earlier on the ridges. The corn crop and the yield of dry matter were higher by 15%-37% on the ridges than on a flat surface.

Received April 20, 1960

BIBLIOGRAPHY

1. BEL'SKAYA, L. T. 1959. Two thousand centers of corn per hectare. Kukuruza. No. 4.

2. BACHELU, YE. KOLING, and LAVLIT. 1957. Ridge cultivation as a means of

conserving soils and water. Sel'skoye khozyaystvo za rubezhom. No. 2.

3. VERIGO, S. A. 1948. Dynamics of the moisture content in the soil in the USSR. Tr. po s.-kh. meteorologii. No. 26.

4. VERSHININ, P. V. et al. 1959. Principles of agricultural physics. Moscow, Fizmatgiz.

5. VOROB'YEV, S. A. 1953. Instructions for practical exercises in agriculture. Moscow.

6. GERASIMOV, G. A. 1939. Effect of cultivation and fertilizers on soil temperature and moisture. Tr. Permskogo s.-kh. in-ta. 7 (11).

7. GORBATOVSKIY, O. O. 1894. Instructions for the growing of corn. St. Petersburg.

8. DROZDOV, N. A. 1956. Corn and its growing in Leningrad Oblast'. Leningrad.

9. KISLOV, V. P. 1948. Absorption of scattered radiation by the ridged soil surface. Sb. tr. po agronomich. fizike. No. 4.

10. KOLOSKOV, P. I. 1958. Problems of the agricultural-climatic regionalization of the USSR. Tr. N.-i. in-ta agroklimatologii. No. 6.

11. KOLOSKOV, P. I. 1959. Method of soil ridging under natural conditions of the monsoon climate of the temperate belt. Tr. N.-i. in-ta agroklimatologii. No. 7.

12. KURMANGALIN, N. A. 1936. Agricultural-meteorological evaluation of the ridge cultivation of vegetables in the Far North. Tr. s.-kh. meteorologii. No. 14.

13. NOVAK. 1953. Basic problems of agriculture in the Far East. Kabarovskoye kn. izd-vo.

14. RYABOVA, YE. P. 1957. Ridge cultivation as a thermomeliorative method of growing plants. Problems of agricultural physics. Leningrad.

15. SAPOZHNIKOVA, S. A., M. I. MEL', and V. A. SMIRNOVA. 1952. Agricultural-climatic characterization of the USSR, as applied to the growing of corn. Tr. N.-i. in-ta agroklimatologii. No. 2.

16. SIDOROV, F. F. 1957. Biological characteristics of corn. Leningrad.

17. SOVETOV, A. V. 1959. Selected works. Moscow, Sel'khozgiz.

18. TRANKEVICH, N. N. 1936. Thermal regime of a ridge and flat soil surface. Meteorologiya i gidrologiya No. 9.

19. CHERNENKOV, A. D. 1946. Importance of aeration and oxidation-reduction processes to soil fertility in the podzolic zone. Dissertation, TSKhA.

20. YAKUSHKIN, I. V. 1953. Plant growing. Moscow, Sel'khozgiz.

SECONDARY MINERALS IN THE GREY FOREST SOILS OF BULGARIA

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Secondary minerals, including clay minerals, are of great importance to soil properties and their fertility. Experimental data on this problem have been published in various countries (1, 2, 5). We shall not dwell in this article on the advances achieved in studying clay minerals, since they have been described in the works of Gorbunov (3, 4, 7) as well as in the monographs and transactions of various conferences.

We shall attempt in our study to point out the mineralogical characteristics of highly dispersed minerals, found in the most widespread soil group of Bulgaria, i. e., in grey forest soils. A morphological description and brief characteristic of these soils are given below.

Profile Number 20. A light grey forest soil on granite eluvium near the village of Zanozhene, Vrachanskiy okrug. The soils occupy the slopes and elevations to the south and southwest of Zanozhene. They are characterized by a very low natural fertility, conditioned by a small content of organic matter and mineral nutrients. These are old plowed areas.

A_{plowed} 0-15 cm. Light grey, dry, slightly clay loam, blocky structure-powdered, friable large rubble inclusions, siliceous powdering. No effervescence from acid. Transition clear.

B_1 15-25 cm. Light-grey-brown, dry, coarse clay loam, blocky structure poorly developed. Not effervescence from acid. Transition gradual.

B_2 25-36 cm. Yellow-brown, irregular (uneven) dark spots, coarse clay loam, lumpy structure with not very strongly bound aggregates. Not effervescence from acid. Transition marked.

C_1 36-74 cm. Brown-yellow, uneven coloring, structureless, sandy loam. Not effervescence from acid.

C_2 74-85 cm. Weathered granite.

The light grey forest soils of the fourth subdistrict of the Predgorno-Staroplaninskiy district (8) possess the following characteristics: a shortened profile with well pronounced but thin humus eluvial (20 cm) and illuvial (20-30 cm) horizons. Removal of clay particles from the A_2 horizon and their addition into the B horizon, containing twice as much clay, is particularly pronounced. Accumulation in the humus horizon of SiO_2 is strongly pronounced. Carbonates are missing. Texturally soils are coarse clay loam, but parent material sandy loam.

Profile Number 1. Light grey soils, gleyed, on non-carbonate shale, in the Lovchanskiy Okrug. These soils occupy large areas in the region of the Velchevo cooperative farm and are situated on the more level sections of the severely rugged (broken) mountain terrain. Vegetation consists of oak. After the stumps were grubbed the soils were covered with natural meadows of very diversified and poor quality feed — sour grass and moss. The fine texture of the illuvial horizon and the vegetation cause the water to be retained on the surface in the light of which we find soils under water for a large part of the vegetation period and hence cannot be used for cultivation.

A_1 (sod) 0-13 cm. Light-grey, moist, slightly compacted, small blocky structure, medium clay loam. No effervescence from acid. Transition marked.

A_2 13-30 cm. Light-grey-ashy, moist, slightly compacted, medium clay loam with a well pronounced platy structure. No effervescence from acid, many manganese concretions. Transition abrupt.

B_1 30-42 cm. Grey, with blue shade (tint), moist, compact, lumpy structure, clay. No effervescence from acid. Transition marked.

B_2 42-70 cm. Grey-brown, with blue spots, uneven coloring, moist, more compact than the B_1 horizon, lumpy structure. No effervescence from acid. Transition gradual.

B_3 70-100 cm. Similar to B_2 horizon, differing only by coarser texture.

B_4 100-145 cm. Brown, fresh, very compact, blocky structure, clay. No effervescence from acid. Transition marked.

C_1 145-180 cm. Light-brown, fresh, compact, clay, blocky structure, small lime concretions. Effervescences from acid.

This profile is typical of the soils of the second subdistrict of the Predgorno-Staroplaninskiy district of grey forest soils (8). Typical is a small thickness of the humus horizon (15-20 cm), a great thickness of the illuvial gley horizon, which reaches depths of 200 cm. A siliceous powdering is clearly visible on the surfaces of the structural aggregates in the humus and illuvial horizons. Carbonates are leached to a depth of 90-200 cm.

The profile examined differs from the light-grey forest soils of the second subdistrict by a very strongly pronounced podzolic horizon and severe gleying to the depth of the entire profile, which affects or explains the texture and deterioration of the water-air regime and physical properties. These soils are not suitable for plowing.

Profile Number 1. Grey forest soil on yellow-brown carbonate clay, near the village of Bokhot, Plevenskiy Okrug in an oak forest. The profile of this soil is typical of the grey forest soils of the first subdistrict of the Predgorno-Staroplaninskiy district. They occupy the lower sections of the folded mountain region of the Staraya Plain.

A_1 0-25 cm. Grey, dry, slightly compacted, medium clay loam, with a platy structure in the upper part, in the lower part granular-blocky with siliceous powdering. No effervescence from acid. Transition clear.

B_1 25-55 cm. Brownish-grey, dry, compact, clay, small lumpy structure, small iron-manganese concretions. No effervescence from acid. Transition gradual.

B_2 54-82 cm. Rusty-brown, fresh, very compact, clay, lumpy structure, small iron-manganese concretions. No effervescence from acid. Transition gradual.

B_3 82-125 cm. Brown, with rusty shade (tint), fresh, compact, clay, lumpy structure. No effervescence from acid. Transition gradual.

B_4/C_1 125-150 cm. Yellowish-brown, fresh, compact, fine clay loam, lumpy structure, carbonate streaks and concretions. Effervescences from acid. Transition gradual.

C_1 150-178 cm. Yellowish-brown, fresh, slightly compacted, medium clay loam, structureless, many carbonate streaks, presence of carbonate mycelium and concretions. Effervesces violently from acid.

This soil differs from the light grey forest soils by lesser accumulation of silica, the powdering of which occurs only in the humus horizon. Differentiation in the texture of individual genetic horizons is poorly expressed as compared with light grey and forest soils. The natural fertility of these soils is not too great. These soils possess unfavorable physical properties: a fine texture and a great compact illuvial horizon as well as poor aeration.

Profile Number 13.[1] A dark grey forest soil on red-brown clay, near the village of Tsar' Samiul, Kolarovgradskiy Okrug. The profile describes the dark grey forest soils of the Ludogorsko-Varnenskiy district. These soils occupy the central sections of the Ludogorskoye Plateau. The profile was taken in an oak forest.

---Footnote 1 in next column ---

A_0 0-3 cm. Semi-decomposed and undecomposed deciduous leaves.

A_1 3-5 cm. Light grey, friable, powdered structure, coarse clay loam. No effervescence from acid. Transition gradual.

A_1 5-18 cm. Grey, variegated plant mold, friable, dry granular structure, medium clay loam. No effervescence from acid.

A_2/B_1 18-36 cm. Grey brown, dry, small lumpy structure, fine clay loam. No effervescence from acid, siliceous powdering. Transition marked.

B_2 36-57 cm. Brown, unevenly colored, medium compact, lumpy structure, fine clay loam. No effervescence from acid. Transition gradual.

B_3 56-117 cm. Brown, compact, with small manganese concretions, lumpy structure. No effervescence. Transition gradual.

B/C 117-135 cm. Light-brown with red tint, fresh, fine clay loam, lumpy structure. No effervescence. Transition marked.

C_1 135-160 cm. Red-brown, compacted, lumpy structure, fine clay loam, carbonate mycelium and concretions.

In order to study the highly dispersed minerals of grey forest soils we took from each profile 3-4 samples (conforming to genetic horizons) and separated from them fractions < 0.001 mm in diameter, according to Gorbunov's (6) methods. The clay fractions were examined by a complex of methods; thermographic, X-ray, and electron microscope.[2] In addition, we studied the chemical composition and certain physico-chemical properties.

Figure 1 shows the thermograms of the clay fractions. Below are given a description of these thermograms and their interpretation.

1. Light grey soil on granite eluvium, profile number 20, depth 0-10, 18-22, 25-35, and 40-50 cm. Endothermic effects at 100-110°C 575-580°C and exothermic effects at 925-935°C are present on all thermograms. In addition, small endothermic effects, the magnitude of which increases downwards, occur at 280°C. We note a sharp curve at 575-580°C

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[1] The morphological description of profile number 13 is given by Yevg. Tanov and of profile 1^a by A. Ralchev.

[2] Mineralogical investigations were carried out in the Mineralogy Laboratory of the V.V. Dokuchayev Soil Institute under the direction of N.I. Gorbunov.

and 925-935°C.

Interpretation. Minerals of the kaolinite group (kaolinite and halloysite) are predominate in all samples; we find also admixtures of sesquioxide minerals (goethite, gibbsite); the amount of gibbsite increases with soil depth. Small admixtures of hydromicas and amorphous substances are likely.

2. Light grey soil, gleyed, on noncarbonate shale, profile number 1^a, depth 18-28, 30-40, 80-90, and 150-160 cm. Endothermic effects were detected on all thermograms with maximums at 100°C, 540-550°C, 835-850°C, while small effects were detected at 275-390°C on thermograms for samples from a depth of 18-28 cm and 30-40 cm. We see exothermic effects on all thermograms at 900-940°C.

Interpretation. Minerals of the montmorillonite group and of hydromica are present in all samples. The percent of minerals of the montmorillonite group increases somewhat at a depth of 30-40 cm with a simultaneous decrease in the quantity of hydromicas. We find at a depth of 18-28 cm and 30-40 cm a small admixture of sesquioxide minerals (a mixture of gibbsite and goethite). The hydrophilic nature of the clay fraction increases downwards and reaches a maximum in a sample taken from a depth of 80-90 cm, probably as a result of the accumulation of amorphous hydrophilic colloids. We see an admixture of minerals of the kaolinite group at a depth of 30-40, 80-90, and 150-160 cm.

3. Grey forest soil on carbonate clay, profile number 1, depth 0-25 cm, 65-75 cm, 160-170 cm. Endothermic effects with maximums at 100°C were detected on the thermograms, while in samples taken from a depth of 65-75 cm and 160-170 cm maximums were detected at 195-200°C; we find endothermic effects at 550-560°C, 860-880°C and small effects at 295-375°C on all thermograms. We see an endothermic effect at 680°C in a sample taken from a depth of 160-170 cm. Exothermic effects have been observed at 915-950°C.

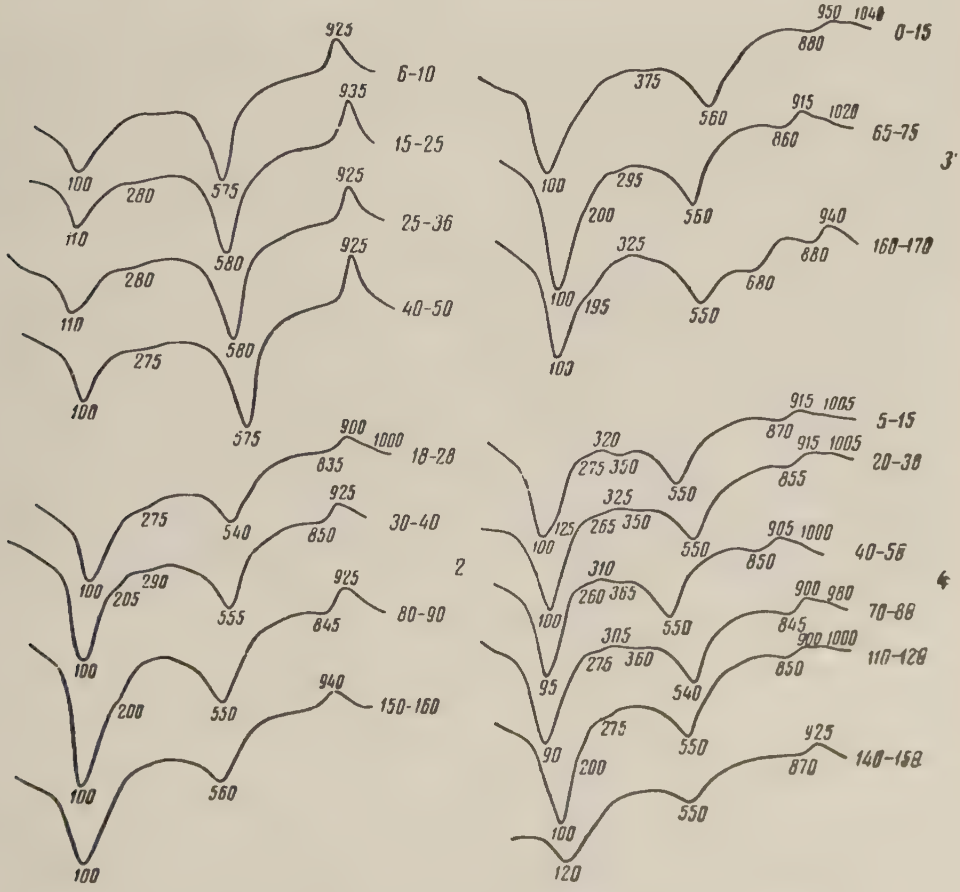

Fig. 1. - Thermograms of fractions < 0.001 mm in diameter, separated from the grey forest soils of Bulgaria.

1 - Profile Number 20. Light grey forest soil on granite; 2 - Profile Number 1^a. Same; gleyed on noncarbonate shale; 3 - Profile Number 1. Grey forest soil on carbonate clay; 4 - Profile Number 13. Dark grey forest soil on red-brown clay.

Interpretation. Hydromicas mixed with minerals of the montmorillonite group are predominant in all samples. The percentage of hydromicas as compared with profile number 1^a is greater, while there are less minerals of the montmorillonite group. The percentage of these minerals increases somewhat downward through the profile. There are a few crystallized sesquioxide minerals. The decrease in the percentage of hydromicas downwards is attended by a decrease in the amount of potassium in the samples (Table 1). The hydrophilic nature of the profile increases downwards but not sharply.

4. Dark grey forest soil on red brown clay, profile number 13, depth 5-15, 20-30, 40-50, 70-80, 110-120, and 140-150 cm. The thermic effects of hydromicas were detected on the thermograms. In addition, we see small endothermic effects at 260-375°C on the thermograms of samples taken from the middle portion of the profile.

Interpretation. Hydromicas are predominant in all samples, while in the middle of the profile there is present a small admixture of crystallized sesquioxide minerals: goethite and gibbsite (effects at 275-350°C). The hydrophilic nature of the samples increases from the top downward but is considerably less than in profile number 1^a and 1.

Based on this interpretation of the thermograms the following mineral associations become apparent.

Kaolinite minerals, which have been accumulated as a result of the weathering of ancient rock-granite- and of a leaching water regime during which these soils are developed are predominant in light grey forest soils on granite eluvium (Profile Number 20). As regards the weaker hydrophilic nature and swelling of kaolinite minerals, these soils have comparatively favorable water physical properties. A finer texture of the B horizon is due to the admixture of hydromicas and amorphous substances.

The light grey forest soil on noncarbonate shale (Profile Number 1^a) is characterized by a montmorillonite-hydromicaceous association of minerals with a predominance of montmorillonite over hydromica. Minerals of the montmorillonite group increase noticeably with depth, which, apparently, is explained by the movement of montmorillonite as the most highly dispersed mineral.

The unfavorable water physical properties of these soils can be explained by the presence of montmorillonite minerals in their illuvial horizons. Montmorillonite holds large quantities of water in its crystal lattice and is conducive to the excess moistening of the soils. The result is a poor water-air regime. The unfavorable properties of these soils are also due to the presence of highly dispersed amorphous minerals at a depth of 80-90 cm.

A hydromicaceous-montmorillonite accociation was likewise detected in the grey forest

Table 1

Content of K_2O and Na_2O in a clay fraction of grey forest soils, %

Soil	Horizon and depth, cm	K_2O	Na_2O	Content of part.diam. < 0.001. %
Profile Number 20. Light grey forest soil on granite eluvium	A_1 0—10	1,06	0,30	6,9
	B_1 18—22	1,04	0,23	10,4
	B_2 25—35	0,92	0,24	12,7
	C 40—50	0,82	0,19	13,7
Profile Number 1^a. Light grey forest soil on non-carbonate shale	A_2 18—28	1,20	0,23	18,2
	B_1 30—40	1,10	0,10	47,2
	B_3 80—90	1,40	0,27	46,9
	C 150—160	1,30	0,32	45,2
Profile Number 1. Grey forest soil on carbonate clay.	A_1 0—25	1,93	0,19	23,7
	B_2 65—75	1,61	0,13	40,3
	C_2 160—170	1,34	0,10	30,9
Profile Number 13. Dark grey forest soil on red-brown clay	A_1'' 5—15	1,78	0,38	28,3
	A_2/B_1 20—30	1,78	0,28	34,5
	B_2 40—50	1,57	0,34	38,5
	B_3 70—80	1,51	0,35	35,2
	B_3 110—120	1,59	0,24	37,2
	C 140—150	1,74	0,27	29,6

Note: Comma represents decimal point.

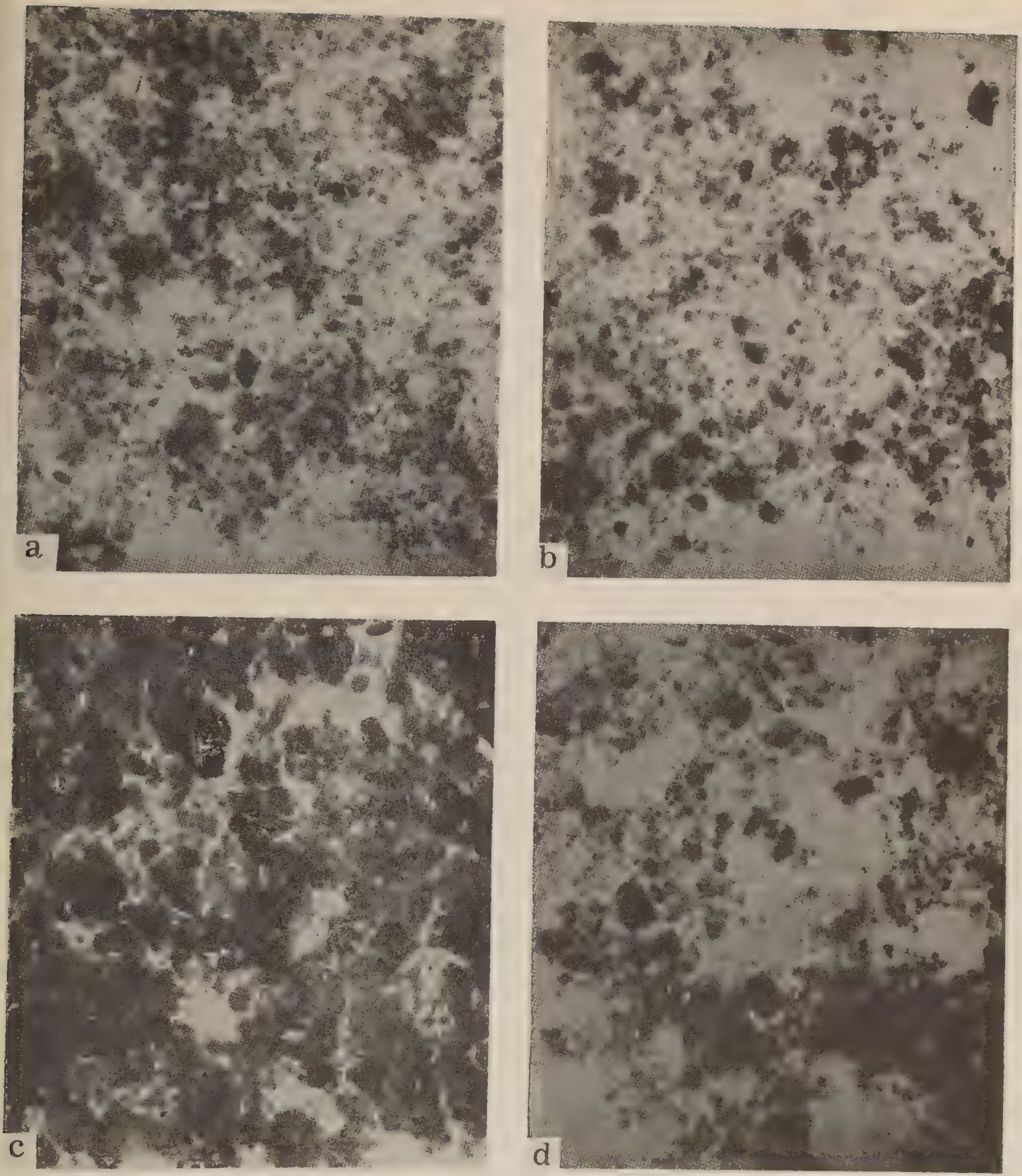

Fig. 2. - Electron microscope photographs X10,000.
a - light grey forest soil on granite eluvium, profile number 20, B_1 horizon; b - light grey forest soil on noncarbonate shale, profile number 1^a, B_3 horizon 80-90 cm; c - grey forest soil on carbonate clay, profile number 1, A horizon, 0-25 cm; d - dark grey forest soil on red-brown clay, profile number 13, C_1 horizon 140-150 cm.

il on carbonate clay (Profile Number 1), but, opposed to the preceding profile, we find ere a predominance of hydromicas. The dromicas have a less pronounced hydroilic nature and swelling capacity than montorillonite; therefore, in these soils the water not held at the surface and there is no reason r such a severe deterioration in the water-air gime. The great compactness and clay aracter of the B horizon is due to the presce in these horizons of large quantities of montmorillonite minerals.

Hydromicas are predominant in the dark grey forest soils on red-brown clay (Profile Number 13). Therefore, these soils are characterized by a less pronounced hydrophilic nature in comparison with profile numbers 1^a and 1. These soils have many properties in common with chernozems.

The presence of these above-mentioned

mineral associations can be ascertained not only from the thermograms but also from X-ray electron-microscope data and from the potassium content in the clay fraction.

We shall not introduce here the data from X-ray analysis but shall point out typical lines which have been detected on X-ray photographs of oriented aggregates.

Reflections of 7.1, 3.56, and 1.48 kX, typical of kaolinite and reflections of 10, 5, 3.3, 1.50 and 1.52 kX, typical of hydromicaceous minerals were revealed on X-ray photographs from Profile Number 20. In the middle of the profile we noted a base reflection of the first order with 14 kX, indicating the presence of montmorillonite minerals.

On X-ray photographs from Profile Numbers 1^a and 1, we find lines typical of montmorillonite and hydromicaceous minerals — 16, 10, 8.7, 5, 3.3, 1.49 and 1.50 kX, etc. In addition, we can observe on X-ray photographs from Profile Number 1 reflections of 7.1 and 3.5 kX, which are proof of the presence of an admixture of kaolinite.

The X-ray investigations of dark grey forest soils of Profile Number 13 reveal the presence in them of chiefly hydromicaceous minerals and admixtures of kaolinite and montmorillonite (in the middle of the profile). Here, we observed lines of 16.0, 10.0, 7.0, 5.0, 3.57, 3.33, 1.50, 1.52, 1.48 kX, etc. as well as reflections of 4.82, 2.38, 1.69 and 1.45 kX, characteristic of goethite and gibbsite.

Electron microscope investigation data have made it possible for us to establish the presence of the same clay minerals found by thermographic and X-ray methods (Figure 2).

Hexagonal kaolinite crystals and their fragments are visible on electron microscope pictures of a clay fraction of light grey forest soils on granite, (Profile Number 20). In the middle of the profile there may be an admixture of hydromica and montmorillonite (Figure 2a). Crystals with eroded edges of montmorillonite and hydromica, and, from time to time, admixtures of kaolinite can be clearly seen on micro-photographs of a grey forest soil on noncarbonate clay (Figure 2b). Montmorillonite minerals and hydromica together with a kaolinite admixture have been expressed even on photographs of a grey forest soil on carbonate clay. Here we observe isolated rods of halloysite.

The electron-microscope photographs of a clay fraction of dark grey forest soils on red-brown clay (Profile Number 13) show the following. Hydromicaceous minerals predominate in the upper part of the profile. Kaolinite is present as admixtures. In the middle of the profile we find hydromicas mixed with montmorillonite, while in the lower part of the profile and in the parent material there are present hydromicas, an admixture of montmorillonite and kaolinite, and isolated crystals of halloysite. In addition, we find here sesquioxide minerals.

The potassium content in the clay fraction is proof of the presence of a considerable quantity of hydromica in the soils. We see from Table 1 that the percentage of potassium oxide in the various soils varies, not less however than 1.10%.

The percentage of K_2O is least in the light grey, forest soils on non-carbonate shale where montmorillonite minerals and, less so, hydromicas predominate.

The total chemical composition shows the following (Table 2). The humus A_2 horizon of light grey forest soils on noncarbonate shale (Profile Number 1^a) contains the largest amount of SiO_2 — 77.27% (Table 2), and a small amount

Table 2

Total chemical composition of grey forest soils, % of ignited sample

Soil	Horizon and depth, cm	SiO_2	R_2O_3	F_2O_3	Al_2O_3	CaO	MgO	K_2O	Na_2O
Profile Number 1^a. Velchevo. Light grey forest soil on noncarbonate shale	A_2 12—22	77,27	19.98	9,85	10,13	0,26	0,72	0,85	0,80
	B_1 30—40	69.66	25,30	9,74	10,26	0,74	0.21	1,51	0,70
	B_3 80—90	68,35	25,37	8,88	21,29	1,78	1,24	1,54	0,73
	C_1 150—160	69,87	23,33	7,18	16,15	0,40	1,24	1,23	0,65
Profile Number 1. Bokhot. Grey forest soil on yellow-brown carbonate clay	A_1 0—25	73,45	19,26	6,14	13,04	2,26	0,79	1,98	1,29
	B_2 65—75	61,40	32,02	7,23	16,46	1,32	0,32	1,98	0,92
	C_2 160—170	57,26	34,20	5,05	29,15	5,91	0,41	2,00	1,15
Profile Number 13. Dark grey forest soil on red-brown clay	A_1'' 5—15	73,73	20,02	7,05	13,86	1,14	0,30	1,93	1,27

Note: Comma represents decimal point.

of sesquioxides -- 19.9%. In grey forest soils on carbonate clay (Profile Number 1) and in dark grey forest soils on red-brown clay (Profile Number 13) there is less SiO_2 in the upper horizons than in Profile 1[a].

Conclusions

1. Light grey forest soils on granite eluvium contain mostly kaolinite minerals; admixtures of hydromicas, sesquioxide minerals and montmorillonite are present. The comparatively favorable water-physical properties of these soils can be explained by the predominance of the kaolinite minerals.

2. Light grey forest soils on noncarbonate clay contain chiefly minerals of a montmorillonite-hydromicaceous association with predominance of montmorillonite minerals over hydromicaceous minerals. We find kaolinite minerals and sesquioxide minerals (goethite, gibbsite) occuring as an admixture. The presence of large quantities of montmorillonite minerals produces less favorable water-physical properties in these soils.

3. Grey forest soils on carbonate clay contain likewise montmorillonite minerals and hydromicas, but here the hydromicas are predominant. Therefore, the water physical properties of these soils are not as favorable, as in light grey forest soils on noncarbonate shale. We detected a small increase in the percentage of montmorillonite in the middle of the profile. Crystallized sesquioxide minerals are present in small number.

4. Dark grey forest soils on red-brown clay contain chiefly hydromicas. Montmorillonite is found as an admixture in the middle and lower part of the profile. Sesquioxide minerals (goethite, gibbsite) were also detected.

5. Data on K_2O content in a clay fraction of the soils reveal the presence in them of large quantities of hydromicas.

6. The total chemical composition of the soil as a whole reflects the podzolization process in the light grey forest soils on noncarbonate shale. The podzolization process in the other two profiles studied is less strongly pronounced.

Received December 20, 1960

BIBLIOGRAPHY

1. BRINDLY, T. V., and others. 1951. X-ray methods for determining clay minerals. Translated from English, London.
2. GRIMM, R. 1956. Mineralogy of clay. Translated from English. Moscow.
3. GORBUNOV, N. I. 1946. The X-ray and electronographic method of studying colloids. Pochvovedeniye No. 8.
4. GORBUNOV, N. I. 1957. The electron microscope investigation of soil colloids. Pochvovedeniye No. 8.
5. GORBUNOV, N. I. 1955. Clay minerals of chernozems, chestnut, and solonetz-like soils. Pochvovedeniye No. 11.
6. GORBUNOV, N. I. 1960. Methods of separating soils and clay into fractions for X-ray and thermographic study. Pochvovedeniye No. 11.
7. GORBUNOV, N. I. 1957. Advances in the study of highly dispersed soil minerals. Pochvovedeniye No. 10.
8. SOFIA. 1960. Soils of Bulgaria (In Bulgarian).

USE OF PAPER ELECTROPHORESIS FOR FRACTIONATION OF THE HUMIC SUBSTANCES OF SOIL AND FOR STUDY OF THEIR COMPLEX COMPOUNDS WITH IRON

M. M. KONONOVA, and N. A. TITOVA

One of the important properties of the humic substances of soil is their heterogeneity. Both humic and fulvic acids can be separated into several fractions by many means — by fractional precipitation in solutions, ultra-centrifugation, electrophoresis, and various forms of chromatography. Such properties of humic substances, as dispersion, ratio to electrolytes, participation in exchange reactions and others, being of great importance for soil process, are determined to a considerable extent by the nature and ratio of fractions.

The electrophoresis method, which is being widely used in biochemistry, microbiology, and other biological disciplines for isolating mixtures of individual compounds (for example, mixtures of amino acids and sugars) and for fractionation of highly molecular compounds (for example, proteins) is used by a number of investigators in studying soil humic substances (8, 23, 18, 24, 19, 20, 21, 14, 26, 12, etc.).

These studies revealed that humic substances travel from the starting point toward the anode and are isolated at the same time into fractions, forming zones. The number of fractions depends upon the nature of the substance. Thus, with short-term electrophoresis using a buffer of a weakly alkaline reaction (pH — 8.6) and with a voltage of 110-300 the natural and artificially prepared humic acids are separated into 3-4 fractions, one of which — the fluorescent fraction — can be seen in an ultraviolet light. When voltage is higher and electrophoresis continuous, it is possible to separate humic substances into a larger number of fractions (4, 21).

Certain characteristics of the fractional composition of humic acids of varied origin became apparent by using electrophoresis. Scheffer (19) notes that during electrophoresis of grey humic acids rich in nitrogen, clearer zones are obtained than during electrophoresis of brown humic acids. Kaurichev and co-authors (4) have found that fractions having a high optical density are predominant in the humic acids from soils of the chernozem type, while in podzolic soils and in red earth the fluorescent fractions characterized by low optical density are predominant.

The electrophoresis method can be used to study the phenomenon of the complex formation of humic substances; Drozdova and Yemel'yanova·(3) have established that during the interaction with cooper of a humic acid isolated from peat there are formed, depending upon the quantitative ratios of reagent components both soluble, mobile intracomplex compounds as well as insoluble complexes.

We used the electrophoresis method for fractionation of humic substances and for study of their complexes with iron. We studied the compounds of humic substances isolated from different soils, as well as soil extracts obtained using a 0.1 M solution of sodium pyrophosphate (pH — 7). The results of these studies are given in this article.

1. Conditions for Conducting Electrophoresis

We used an EFA-1 apparatus (physical instruments plant) for horizontal electrophoresis consisting of an electrophoretic chamber, a supply source, and a recorder (densitometer). In the chamber the substance to be studied was isolated into fractions in an electrostatic field, formed between carbon electrodes lowered into the buffer solution.

We adopted for our investigations the following methods based on preliminary conducted systematic research (Table 1).

For phoregrams we used a slowly filtering chromatographic paper (manufactured by the Leningrad Plant imeni Dzerzhinskiy) from which we cut out strips 2.5 cm wide and 40 cm long.

We applied the solution being studied on the starting line selected beforehand at the center of the strip (an equal distance between anode and cathode) using a calibrated microburet with a volume of 0.018 ml and we dried the solution under a desiccator. In the event of a low concentration of organic substances in the solution we applied several volumes of the microburet on paper. After drying the strip we quickly wetted it with a buffer solution and placed it into the chamber, lowering the strip ends into the vessels of the same solution. We placed nine strips into the chamber at one time; accordingly, the voltage on a 1 cm wide strip was about 20 (500 volts: 2.5 cmx9). Upon completion of fractionation the phoregrams were removed from

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Table 1

Conditions for conducting electrophoresis

Voltage, v		Strength of current, milliamperes		Fractionation time, hours	pH of buffer (borate) solution
Begin.	End	Begin.	End		
500	460	20	42.0	1.5—2	8.6

the chamber and quickly dried under a desiccator.

2. Fractionation of Humic Substances of Various Soils using Electrophoresis

We used as subjects for this branch of study compounds of humic acids isolated by our accepted methods (5, 6) taken from an upper (0-20 cm) horizon of ordinary chernozem (Kamennaya Steppe, Voronezhskaya Oblast') and of a sod-podzolic soil (Moskovskaya Oblast') from a humus illuvial horizon (16-24 cm) of a strongly podzolic soil (Arkhangel'skaya Oblast') as well as a compound of fulvic acids taken from red earth (the Chinese People's Republic) obtained from the research student

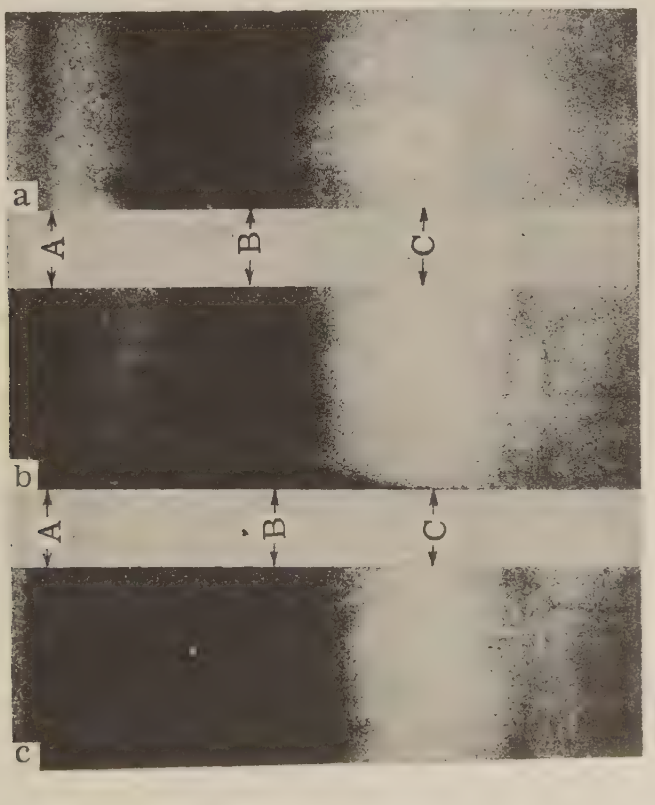

Fig. 1. - Electrophoregrams of humic substances (photo taken in ultraviolet light).
a - fulvic acids from the earth; b - humic acid from sod-podzolic soil; c - humic acid from chernozem. Zones: A - at the start; B - brown, moving; C - fluorescent.

Table 2

Elementary composition of humic substances, in percent of absolutely dry ash-free substance

Substance investigated	C	H	O	N	C:H	Ash, %
Humic acids from:						
A humus illuvial horizon	58,11	5,37	32,00	4,52	10,8	7,09
A sod-podzolic soil	57,63	5,23	32,33	4,81	11,0	2,96
Ordinary chernozem	62,13	2,91	31,38	3,58	21,4	4,19
Fulvic acids from red earth	40,92	4,33	52,14	2,61	9,5	7,53

Note: Comma represents decimal point.

Comrade Nyu Tszi-ven'. The differences in the nature of the humic substances of the various soil groups (5, 6), as established by earlier investigations, are corroborated by the data in Table 2 on the elementary composition of the subjects being studied. Thus, a high percentage of carbon and a low percentage of hydrogen and, correspondingly, a wide ratio of C:H in the chernozem humic acid is proof of the presence of a condensed aromatic nucleus which distinguishes this humic acid from the other humic acids under study, particularly from fulvic acids.

Preparation of solutions of humic substances for electrophoresis was as follows. Small weighed samples (0.01-0.02 g) of compounds were dissolved in 0.02 n NaOH by adding that amount of NaOH which would bring the final pH of the solutions to 8-8.5. To obtain a complete solution, tumblers or breakers containing the substance were placed in a hot water bath. The carbon content was determined in the solutions obtained and volumes containing an amount of C substance equal to all subjects being studied were applied on paper using a microburet (in this experiment C amounted to 0.15 mg).

During the electrophoresis humic substances travelled from the starting point toward the anode; two zones were detected on the phoregrams in daylight: the first (zone A), formed by a fraction of the substance remaining at the start and a second zone (Zone B) formed by a mobile fraction, being of brown rusty color and found a certain distance from the start. A third zone (C), fluorescing with a greenish yellow light, can be seen under an ultraviolet light directly after zone B (Fig. 1 a, b, c).

Certain features in the distribution of the substances by zones became apparent in comparing phoregrams. This is illustrated by the curves recorded using a densitometer (Fig. 2). In a chernozem humic acid (Figure 2a) the high peak, corresponding to Zone A, indicates that a larger part of the substance is left at the start

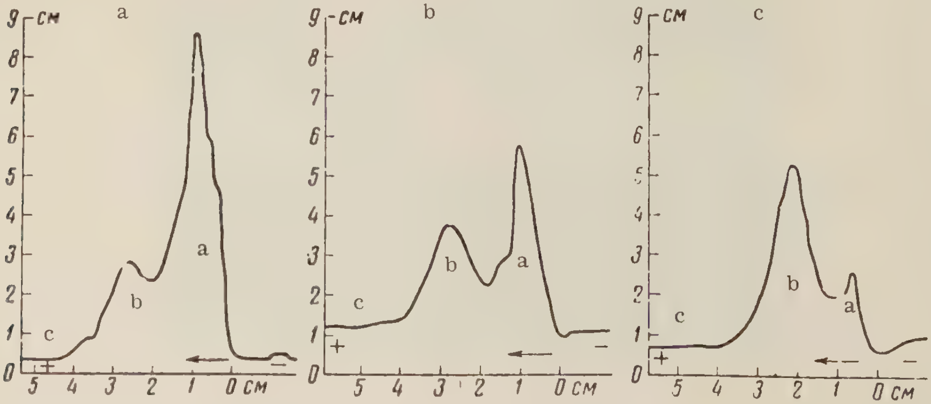

Fig. 2. - Character of humic acid distribution on phoregrams, (curves, recorded using a densitometer).
a - from chernozem; b - from sod-podzolic soil; c - from a humus illuvial horizon of strongly podzolic soil. Zones: A - at the start; B - brown, moving C - fluorescent.

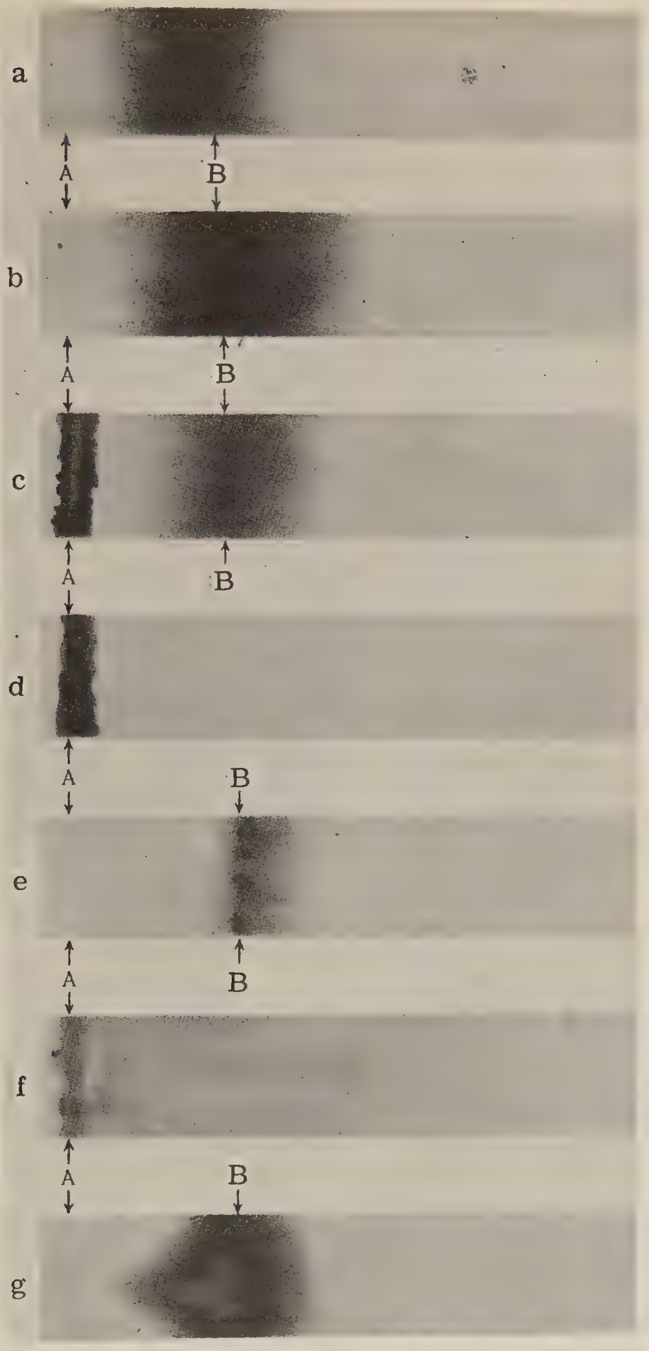

Fig. 3. - Electrophoregrams of humic substances treated by an acidified solution of $K_4 [Fe(CN)_6]$.
a - fulvic acids from red earth; b - humic acid from a humus illuvial horizon of strongly podzolic soil; c - humic acid from a sod-podzolic soil saturated with iron; d - humic acid from chernozem saturated with iron; e - extent (0.1 M solution of sodium pyrophosphate, pH = 7) from chernozem; f - same; from a sod podzolic soil; g - same; from a humus illuvial horizon.

and only a small part moves toward the anode.

We observe a different picture on the curve (Figure 2b) of a humic acid from a sod-podzolic soil: here a large part of the substance travels toward the anode forming zone B, and correspondingly, a smaller amount is left at the start. The most intensive movement is observed on a phoregram of a humic acid from a humus illuvial horizon of strongly podzolic soil (Figure 2c) which is indicated by the low peak corresponding to Zone A, and the high peak corresponding to Zone B. In comparing phoregrams and curves (Figure 1 and 2) it is not difficult to see that by character of fractionation the humic acid of a humus illuvial horizon approaches fulvic acids.

Thus, the chernozem humic acids, complex in nature, under our accepted method of electrophoresis were fractionated with difficulty using electrophoresis and, for the most part, were left at the start. On the other hand, mobile fractions are predominant in fulvic acids and in a humic acid from a humus illuvial horizon of strongly podzolic soil, which approaches fulvic acids in nature. The humic acid from a sod-podzolic soil assumes a middle position between these substances.

Let us turn our attention to the fact that the results of fractionation of humic substances from various soils using electrophoresis were similar to the results obtained from distribution starch column (6) and paper (7) chromatography. Remember that by these methods humic acids and fulvic acids were isolated into three fractions among which one was fluorescent. The mobile fraction predominated in fulvic acids, whereas in a chernozem humic acid the larger part of the substance was left at the start.

As was pointed out previously, our objective consisted not only of fractionating humic substances, but also of detecting in their composition complex compounds with iron. Note that despite careful purification (re-precipitation, electrodialysis) humic substances failed to become ash-free, the percentage of which was especially high in the humic acid from a humus illuvial horizon of strongly podzolic soil and in fulvic acids (Table 2). This, apparently, is explained by the presence of stable complexes with mineral elements (in particular, with iron).

To detect iron on the phoregrams we used a 4% solution of potassium ferrocyanide K_4 [Fe $(CN)_6$] acidified by sulfuric acid in order to decompose the iron humic complexes.[1] By such treatment we were able to observe at the point of Zone B a greenish-blue coloring or tint on the phoregram of fulvic acids and of a humic acid from a humus illuvial horizon (Fig. 3a, b).

The presence of organic substances and iron in Zone B of these subjects was established analytically. To obtain a sufficient amount of material we prepared several tens of phoregrams. The B zones were cut out of the phoregrams; the adsorbed substances were easily eluted from the paper by steeping the cut out zones in distilled water. The solutions obtained were filtered and brought to a specific volume; the carbon (using the Tyurin method) and iron (on a FEK-M photocolorimeter with sulfosalicylic acid) were determined in them. To determine the iron in the solution we first oxidized the organic substances by a mixture of concentrated sulfuric and perchloric acids in a ratio of 3:2. In the case of a humic acid from a humus illuvial horizon we found in a solution eluted from 50 phoregrams 21 mg of C and 0.98 mg of Fe_2O_3. In a solution eluted from 20 phoregrams of fulvic acids we found 4.6 mg of C and 0.092 mg of Fe_2O_3. Judging by the number of signs (typical coloring, movement toward the anode) the intra-complex compounds of humic substances with iron (of the chelate type) were found in Zone B of the phoregrams of the preparates studied.

Mobile complexes were not detected on phoregrams of humic acids from chernozem and a sod-podzolic soil. To ascertain the reason for this phenomenon we made the following experiment with an artificial saturation of these acids by iron. We added to the solutions of humic acids in 0.02 n NaOH (with a reaction of 7-7.5) a solution of $FeCl_3$ until the gel was completely precipitated, and we left the solution in this form overnight. Then, we centrifuged the precipitates and carefully washed them in water until Fe^{+++} and Cl^- were entirely removed, after which we dissolved the gel in 0.02 n NaOH which was added in amounts necessary to bring the pH of the solution to 8-8.5. The solutions thus prepared were subjected to electrophoresis by the previously described method.

On a chernozem humic acid phoregram treated with an acidified solution of $K_4[Fe(CN)_6]$ iron was detected only at the start (Figure 3g) where it occurred in the form of non-mobile iron humus complex. On a phoregram of a humic acid from a sod-podzolic soil (Figure 3c) iron was detected at the start and (fairly weakly) in zone B; consequently, in this latter case there occurred a formation of both immobile and mobile iron humus complexes.

Undoubtedly the distinct character of the complex formation in humic substances of varied origin is closely allied with their nature, in particular with the ratio in the molecules of the aromatic nucleus (which is a hydrophobic part of the molecule) to the peripheral chains containing hydrophilic groups.

The smallest condensed nucleus is found in fulvic acids which at the same time contain the largest number of peripheral chains and, correspondingly, the largest number of hydrophilic groups, which explains why fulvic acids tend to form mobile complexes with iron. A similar picture is observed for a humic acid from a humus illuvial horizon of strongly podzolic soil, the nature of which resembles fulvic acids.

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[1] Iron was not detected on the phoregrams when we used a solution of $K_4[Fe(CN)_6]$ without acidification.

The likelihood of forming available (mobile) complexes of humic substances with iron decreases as the degree of condensation of the nucleus increases and as the number of peripheral chains simultaneously decreases. Humic acids from a sod-podzolic soil and, especially from chernozem may be used as an example.

These studies agree with the results obtained by Kawaguchi and Kyuma (15), which indicate a direct relationship between the formation of the chelates Fe^{+++} and Al^{+++} and the content in the humic substances of peripheral chains containing hydrophilic groups. Consequently, these authors note that fulvic acids have the highest chelation coefficient or capacity, which also explains their active role in podzol formation.

The important role belongs to the mobile complex compounds of humus with iron, not only in the podzol formation but also in many other natural phenomena, as, for example, in the accumulation of iron organic compounds, in the supply of this element to plants, etc. In this connection it would be interesting to inquire into the possibility of forming a similar kind of compound in the various soils; some data on this problem is given below.

3. Fractionation of Soil Extracts using Paper Electrophoresis

We took for our investigations soils resembling those from which we isolated compounds of humic substances (see preceding section): a humus illuvial horizon (50-60 cm) of strongly podzolic soil (Susystamo, Karel'skaya ASSR) and the upper (0-20 cm) horizons of a sod-podzolic soil (Moskovskaya Oblast') and a thick chernozem (Kurskaya Oblast').

The humic substances were extracted by 0.1 M solution of sodium pyrophosphate (pH -7); its application, like of several neutral salts of organic acids (for example, of sodium salts of oxalic, tartaric, citric, and other acids) used to isolate humic substances from soil was based on the ability of the solutions of these salts to form insoluble precipitates or soluble complexes with calcium, trivalent and with certain other polyvalent cations with which the humic substances in the soil are associated. Many authors used sodium pyrophosphate to extract humic substances from soils and peat (10, 9, 16, 17, 22, 11, 2, 25, 1, etc.).

We established, by preliminary experiments, that mobile complexes of humic substances with iron are most clearly evident during the electrophoresis of extracts obtained by 0.1 M solution of $Na_4P_2O_7$ with a neutral reaction (pH — 7) and when there is a narrow ratio between soil and the solvent (1:5 or 1:3).

The extracts were prepared by digesting the weighed soil samples (5 g) with 25 ml of a given solution of $Na_4P_2O_7$ for approximately 18 hours, after which the extracts were filtered through a dense paper filter and repeatedly centrifuged until the solution was completely transparent without adding coagulators.

The carbon content was determined in the prepared extracts and the solution using the previously described method was applied on paper strips and electrophoresis performed. The phoregrams after drying were sprinkled with 4% solution of $K_4[Fe(CN)_6]$ acidified by sulfuric acid. Table 3 gives data on the carbon content in the initial soil, in the extract, and in the volume of the solution applied to the phoregram.

As we see from the data in Table 3, 0.1 M of solution of $Na_4P_2O_7$ (pH — 7) extracts from a humus illuvial horizon of strongly podzolic soil more than 60% of the entire organic carbon of the soil, whereas from a sod podzolic soil it extracts about 20% and from thick chernozem a total of only about 14%. We may assume that $Na_4P_2O_7$ extracts from soils, besides humic acids and fulvic acids, certain organic compounds of an individual nature, also.

During electrophoresis of the extracts it became evident that the substances from the start travelled toward the anode, forming zones. When the phoregrams were sprinkled with an acidified 4% solution of $K_4[Fe(CN)_6]$ at the point of zone B, iron was detected very clearly in the extract from a humus illuvial horizon of strongly podzolic soil (Figure 3g), and less clearly from chernozem (Figure 3e).

On a phoregram of an extract from sod podzolic soil (Figure 3f) the mobile iron humus

Table 3

Carbon content in the initial soils and extracts of 0.1 M sodium pyrophosphate (pH — 7)

Soil and location	Organic C in the soil, %	C Extracts		Applied to a phoregram, mg, C
		% of soil weight	% of C of soil	
Humus illuvial horizon of strongly podzolic soil, Suystamo	8,10	4,90	60,5	0,40
Sod podzolic soil, Moskovskaya Oblast'	0,91	0,18	19,9	0,08
Thick chernozem, Kurskaya Oblast'	4,19	0.57	13,6	0,07

Note: Comma represents decimal point.

complex was not detected, obviously because of its low content in the volume of extract used for electrophoresis. In this instance sodium pyrophosphate compounds with iron of the same soil will form a blue background on the phoregram. A similar situation is seen on phoregrams of our artificially prepared iron complexes with sodium pyrophosphate without participation of humic substances.

These data reveal the possibility of the formation of mobile iron humus complexes in various soils. Besides fulvic acids and individual organic compounds, (in particular, low molecular organic acids) even humic acids resembling in nature fulvic acids may participate in their formation: such situations do occur in strongly podzolic soils. In chernozem owing to the complex structure of the humic acids, these complexes play no role in this phenomenon; here fulvic acids and certain individual organic compounds participate in the formation of the mobile iron humus complexes.

Conclusions

1. By using paper electrophoresis conducted over 1.5-2 hours with a total voltage of 500-460 (20 volts per cm of strip width), humic acids (from ordinary chernozem, sod podzolic soil, and a humus illuvial horizon of strongly podzolic soils) as well as fulvic acids from red earth are separated into three fractions: one fraction left at the start (zone A) and fractions travelling toward the anode (Zones B and C) of which the latter fraction fluoresces in an ultraviolet light. The fraction ratio in the different humic substances varies.

2. When phoregrams are sprinkled with a 4% solution of $K_4\ [Fe(CN)_6]$ acidified by sulfuric acid, iron is detected in zone B of the fulvic acids and of a humic acid from a humus illuvial horizon. In a solution of substances eluted from zone B of these subjects, iron and organic carbon are quantitatively determined which confirms the presence of an iron-humus complex. The mobile complexes were not detected on the phoregrams of humic acids from a sod podzolic soil and chernozem.

3. The tendency, expressed differently in the various humic substances, to form mobile complexes with iron is explained by the characteristics of their structure, in particular by the ratio of the molecules of the aromatic nucleus [which is a hydrophobic part of the molecule] to the peripheral chains containing hydrophilic groups.

4. Mobile iron humus complexes were isolated from soils by 0.1 M of sodium pyrophosphate [pH -7] and detected by the electrophoresis method.

Various organic substances may participate in the formation of similar kind complexes in the soil: fulvic acids, certain organic compounds of an individual nature (in particular, organic low molecular acids) and in certain soils (as for example, in strongly podzolic) also humic acids, resembling in nature the fulvic acids.

BIBLIOGRAPHY

1. ALEKSANDROVA, L. N. 1960. Use of sodium pyrophosphate for isolating from soil free humic substances, and their organic mineral compounds. Pochvovedeniye No. 2.
2. DROZDOVA, T. V. 1959. The spectral photometry method of determining the quantity of humic acids in peat and peat bog soils. Pochvovedeniye No. 7.
3. DROZDOVA, T. V., and M. P. YEMEL'YANOVA. 1960. Intracomplex copper compounds with humic acids. Doklady Akad. Nauk, SSSR, 131 (3).
4. KAURICHEV, I. S., YE. A. FEDEROV and I. A. SHNABEL'. 1960. Use of the continuous paper electrophoresis method for isolating humic acids. Pochvovedeniye No. 10.
5. KONONOVA, M. M. 1956. Humus of the principal soil groups of the USSR, its nature and methods of formation. Pochvovedeniye No. 3.
6. KONONOVA, M. M., N. P. BEL'CHIKOVA, and V. K. NIKIFOROV. 1958. Use of the chromatographic method in studying the nature of soil humic substances. Pochvovedeniye No. 3.
7. KONONOVA, M. M. and N. P. BEL'CHIKOVA. 1960. Study of the nature of soil humic substances by fractionation methods. Pochvovedeniye No. 11.
8. BEUTELSPACHER, H. 1952. Physikalisch-chemische Beiträge zur Humusforschung. Z. Pflanzenernähr., Düng. Bodenkunde, B. 57 (102), S. 57. (In German).
9. BREMNER, J., H. LEES. 1949. Studies on soil organic matter, p II. The extraction of organic matter from soil by neutral reagents. J. Agric. Sci. v. 39, p. 274. (In English).
10. BREMNER, J., P. MANN, S. HEINTZE, H. LEES. 1946. Metallo-organic complexes in soil. Nature, v. 158, p. 790. (In English).
11. CHOUDRI, M., F. STEVENSON. 1957. Extraction of organic matter from soil. Soil Sci. Soc. America Proc. vo. 21, p. 508. (In English).
12. COULSON, C., R. DAVIES, E. KHAN. 1959. Studies in the fractionation of humic acids J. Soil Sci. v. 10, p. 271. (In English).
13. EVANS, L. 1959. The use of chelating reagents and alkaline solution in soil organic matter extraction. J. Soil Sci. Vol. 10, p. 110. (In English).
14. FLAIG, W., F. SCHEFFER, B. KLAMROTH. 1955. Zur Kenntnis der Huminsäuren. VIII Mitteilung zur Charakterisierung der Huminsäuren des Bodens. Z. Pflanzenernähr. Düng., Bodenkunde, B. 71 (116), S. 33. (In German).

15. KAWAGUCHI, K., K. KYUMA. 1959. On the complex formation between soil humus and polyvalent cations. Soil and Plant Food, v. 5, p. 54. (In English).

16. KOSAKA, Y., A. IZEKI. 1956. Studies on the association of humic acid in soils. Soil and Plant Food, v. 2, p. 8. (In English).

17. OKUDA, A., S. HORI. 1956. Some aspects of humic acid. Soil and Plant Food, vol. 2, p. 42. (In English).

18. PAVEL, L., Y. KOLOUSEK, V. K. SMATLAK. 1953. poznani huminovych latek. No. 3. (In Czech).

19. SCHEFFER, F. 1954. Neurere Erkenntnisse in der Humusforschung. Trans. Vth Intern. Congr. Soil Sci., Leopoidville, v. 1, p. 208. (In German).

20. SCHEFFER, F., W. ZIECHMANN, H. SCHLÜTER. 1955. Die Papierelektrophorese als Möglichkeit der Auftrennung von Huminsäuren. Z. Pflanzenernähr., Düng., Bodenkunde, B 70 (115), S. 260. (In German).

21. SCHEFFER, F., W. ZIECHMANN, H. SCHLÜTER. 1959. Über die Anwendung der Papierelektrophorese zur Trennung von Huminsäuren und die Charakterisierung der gewonnenen Fraktionen. Z. Pflanzenennärh., Düng, Bodenkunde B 85. S. 32. (In German).

22. SPRINGER, U., J. KLEE. 1958. Dde Characterisierung und Unterscheidung von Waldhumusformen mittels der Natronlauge und Natriumpyrophosphat Extraktion und der Stickstoff-Franktionierung. Z. Pflanzenernähr., Düng., Bodenkunde, B. 80, No. 2. (In German).

23. STEVENSON, F. Y. MARKS, Y. VARNER, W. MARTIN. 1952. Electrophoretic and chromatographic investigation of clay-adsorbed organic colloids. Soil Sci. Soc. Am. Proc. vol. 16, pp. 69. (In English).

24. THIELE, H., H. KETTNER. 1953. Über Huminsäuren. Kolloid-Z., B. 130, S. 131. (In German).

25. WALDRON, A., J. MORTENSEN. 1961. Soil Nitrogen Complexes II. Electrophoretic separation of organic components. Soil Sci. Soc. America Proc. vo. 25, p. 29.

26. WELTE, E. 1955. Neuere Ergebnisse der Humusforschung. Angew. Chemie, B. 67. S. 153.

WATER PERMEABILITY OF FROZEN SOILS AFTER VARIOUS METHODS OF TILLAGE

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In the steppe and forest-steppe regions of our country the deciding condition for obtaining a high yield from agricultural crops is the presence of moisture in the soil. Various methods are recommended for maximum moisture accumulation and preservation (1, 2, 3, 4). But the influence of these methods of the infiltration of melt-water into the soil has been insufficiently studied yet.

Shalabanov and Kachinskiy (10, 5) had established earlier that under certain conditions frozen soil lets water through, while a number of investigators noted that soil moisture and methods of tillage have a considerable influence on spring runoff (6, 7, 8. 9).

The Laboratory for Erosion Control and Runoff of the All-Union Scientific-Research Institute of Hydraulics and Melioration is developing methods of laboratory-field forecasting spring runoff on the basis of the water permeability of the soil and the water content in snow (suggested by V. I. Bobchenko) for the purpose of the effective use of moisture retention methods.

The purpose of the present work was to study the infiltration of melt-water into frozen soil under various methods of tillage and various soil moisture conditions. The experiments were conducted on fine clay loam chestnut soils of the Chapayev kolkhoz and on the clay loam chestnut soils of the Engel's Experimental Melioration Station (Saratov Oblast').

As we can see from Table 1, the soils of the Chapayev kolkhoz contain 32.7%-39.1% clay particles, 46.3%-57.1% silty particles and 2.0%-9.1% sand particles and can be classified as silty fine clay loams according to their particle-size composition.

The maximum molecular water capacity (as determined according to the Lebedev method) of the plowed layer is 16.15% and that of the subplow layer, 15.66%. The specific gravity of the soil (in the 0 to 50 cm layer) is 2.62.

Before the beginning of the experiments in the autumn of 1959 when the infiltration plots in Chapayev kolkhoz were saturated with water, the intake rate after an hour was 2.4 mm/min in stubble, 3.3 mm/min in soil plowed in autumn to a depth of 25 cm, and 3.9 mm/min in soil plowed to a depth of 40 cm. This alone bears witness to the considerable difference in the intake rate of water in relation to the depth of soil tillage.

The water intake in the soil was studied in special plots 2 m^2 in area (1.40 x 1.43). The soil around the plots was thoroughly tamped and a small dike 20 cm high built. At the same time, next to each plot an area 0.7 m^2 was treated in the same manner and used as control to determine soil moisture and gas permeability before water intake. Altogether 30 plots and the same number of plots for accompanying observations (moisture, gas permeability) were established.

The experiments were made with three degrees of soil moisture — high, where the plots were amply wetted beginning in autumn, natural, and low moisture, which was achieved by covering the plots.

The period preceding the experiments was characterized by a dry autumn (1959) and a moderately cold winter with little snow and a snow cover 20-25 cm deep. The depth of soil freezing reached 120-130 cm and the soil temperature under the snow varied from -5° to -7°C, increasing to -2°C at a depth of 1 m.

Water intake in the frozen soil was determined prior to snow melting in March 1960. Water was poured over the soil from graduated tanks. The water level was maintained with the aid of a graduated 7 cm ruler. Measurements were made every 10 minutes for 2-5 hours. The water temperature was maintained at 0°C by periodically adding snow to it.

In order to characterize the water intake into frozen soil we presented data obtained in the experiment in Chapayev kolkhoz in a field plowed to a depth of 25 cm in autumn.

The water intake into frozen soil in the first hour was 2.0 mm/min at low moisture, 1.50 mm/min at natural moisture, and 0.25 mm/min at high moisture. There was practically no water entry in the plot with the high moisture content. The given value can be attributed to experimental error, and also to the fact that the loss of water on the formation of an ice crust several millimeters thick was not taken into account (Table 2).

Table 1

Particle-size composition of chestnut soils in the Chapayev kolkhoz, % of dry soil weight

Depth, cm	Ignition loss, %	Particle diameter, mm						
		>1	1—0,25	0,25—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001
0—25	4,79	None	0,02	9,15	32,67	6,69	12,29	39,15
0—25	4,35	»	0,04	5,84	28,67	9,45	18,93	32,72
25—50	12,97	»	0,03	4,60	25,41	10,01	10,89	36,09
25—50	12,97	»	0,07	1,97	28,83	8,51	11,81	35,84

Note: Comma represents decimal point.

Table 2

Moisture of frozen soil before the measurement of water intake, % of dry soil by weight

Degree of wettness	Depth, cm					
	10	20	30	40	50	100
Low	17,5	18,1	17,6	17,4	16,8	15,3
Natural	25.5	22,0	18,5	16,9	15,8	13,0
High	32,1	28,9	24,3	21,8	20,7	17,5

Note: Comma represents decimal point.

Table 3

Water intake into frozen soil (at natural moisture content)

Experimental site	Soil	Soil tillage method	Water intake, mm	
			in 30 min.	in 60 min.
Chapayev kolkhoz	Fine clay loam chestnut	Stubble	35	50
		Plowed to a depth of 25 cm	70	90
		Same, 40 cm	75	100
Engel's Experimental Melioration Station	Clay loam chestnut	Plowed to a depth of 25 cm	60	80
		Plowed without a moldboard to a depth of 30cm	37	49
		Plowed and mole-plowed	137	167

The same relationship between water entry and soil moisture was obtained by us in Chapayev kolkhoz in stubble and in the plot plowed to a depth of 40 cm.

The degree of water filtration into frozen soils after various methods of tillage is of great importance to production. Table 3 gives experimental data on this problem obtained in Chapayev kolkhoz and at the Engel's Experimental Melioration Station (the experiments were made in March 1960).

The obtained characteristics of water intake into frozen soil after various methods of tillage show that water intake increases with increasing depth of plowing. Plowing without a moldboard hardly increased water intake (this is to be verified in later experiments).

Mole plowing of the soil together with autumn plowing increased water entry into frozen soil 2.0-2.3 times as compared to ordinary autumn plowing. With a high level of moisture, when there was practically no water

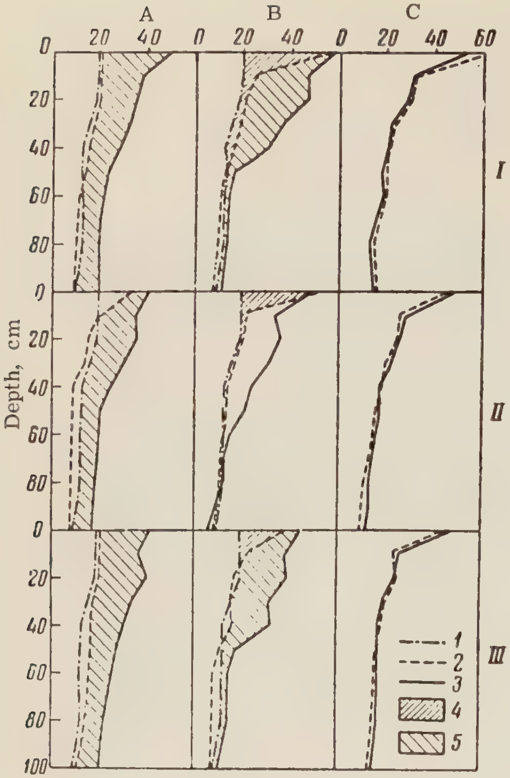

Fig. 1. - Water intake into frozen soil with varying initial soil moisture content and tillage at the Engel's Experimental Melioration Station.
Moisture, % of dry soil on weight basis: A - low; B - natural; C - high. I - plowed to a depth of 25 cm; II - plowed without a moldboard to a depth of 30 cm; III - plowed and mole-plowed. Soil moisture: 1 - before winter; 2 - before the determination of water entry; 3 - after water entry; 4 - increase in moisture during the autumn-winter period, 5 - as a result of the saturation of plots with water.

entry in the autumn-plowed area, water intake reached 30 mm/hr (0.50 mm/min) in the mole-plowed area. Consequently, both mole plowing as well as the other methods of moisture accumulation, associated with the formation of large cracks and cavities in the soil, could considerably increase the water-intake of frozen soils, even with their maximum autumn moistening.

When determining the water-entry of frozen soil the depth of soil wetting was measured in addition to water intake (in mm/min). At the Engel's Experimental Melioration Station the depth of wetting in plots with a low moisture content reached 1 m, in open plots with a natural moisture content, from 50-60 cm, and in plots saturated in autumn there was no wetting. There was practically no difference in the depth of wetting in plots plowed to a depth of 25 cm and those plowed without a moldboard. Plowing with mole plowing increases filtration and the depth of wetting (Fig. 1).

The depth of partial or complete soil thawing after saturation with water was determined by lowering a metal probe into the soil. In the filtration plots with low and natural moisture, thawing reached a depth of 20-40 cm, depending on the method of tillage, then soil wetting reached 0.5-1.0 m, which confirms the conclusions of a number of investigators on the possibility of water entry in frozen soil.

In all cases the water entry into frozen soil was accompanied by the increase in soil temperature to a positive value (+ 1°C), or close to it throughout the entire depth of wetting. The results of soil temperature measurements before water entry and after with plowing to a depth of 25 cm (Chanayev kolkhoz) are presented in Table 4.

Simultaneously with the experiments on water entry we measured the air flowing through frozen soil, in which a hole, 3 cm in diameter and 10 cm deep, was bored. A wooden pipe was driven tightly into the hole to a depth of 5 cm (below 5 cm the hole was left free) and a rubber bulb was fastened to it upper end by which to pump the air, which flowed into the soil through the wooden pipe (Fig. 2).

Table 4

Soil temperature, °C

Time of temperature measurement	Bore-hole No.	Depth, cm					
		10	20	30	40	50	100
Prior to water entry	2	−6,0	−5,0	−4,5	−4,0	−4,0	−2,5
Same	3	−6,0	−5,5	−5,0	−4,5	−4.5	−2,5
After water entry	1	−0,5	−0,5	−0,5	−1,0	−1,0	−1,5
"	2	−0,5	−0,5	−0,5	−1,0	−1,0	−1,5
"	3	0,0	0,0	0,0	−0,5	−0,5	−1,0
"	4	0,0	0,0	0,0	−0,5	−0,5	−1,0

Note: Comma represents decimal point.

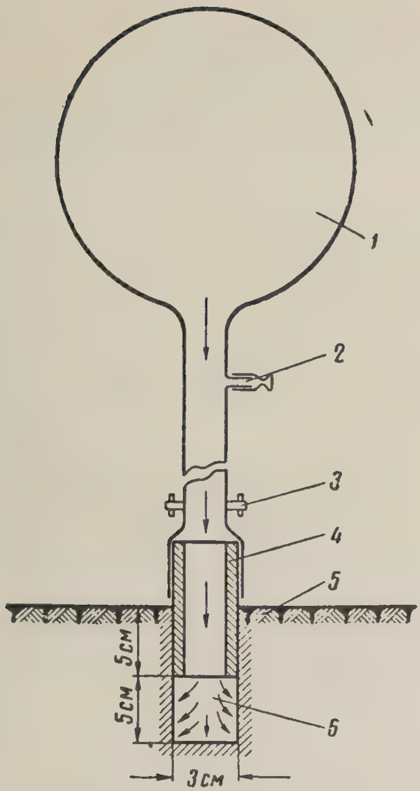

Fig. 2. - Setup for determining air permeability through frozen soil. 1 - rubber bulb; 2 - valve for supplying air into the bulb; 3 - clamp; 4 - tube; 5 - soil surface; 6 - opening for supplying air to the soil. The arrows show the direction of air movement.

The volume of air in the bulb was determined from the circumference of the bulb, which was calibrated in advance, taking into account its circumference, volume, and the air pressure in it. The same wooden tube with the same rubber bulb was used in the experiment, which made it possible to obtain comparative data. The circumference of the bulb was measured every minute for 5 minutes or until the bulb was completely empty of air.

Observations on the flow of air through frozen soil showed that in all covered plots with low moisture (15%-20% at a depth of 10 cm) the air from the bulb entered into the soil in 5-10 sec, in plots with natural moisture (20%-25%) in 180-300 sec, and practically did not enter into the soil in plots saturated with water in autumn and having a high moisture content (80% at a depth of 10 cm).

Conclusions

1. The principal indices of the water-permeability of frozen soils are their moisture content and porosity. Low soil moisture in autumn is an important factor which determines the possibility of wetting frozen soil.

2. Autumn plowing increases the water-permeability of frozen soil about twice with plowing to a depth of 25 cm and by 10%-40% with plowing to a depth of 40 cm.

3. Water entry conditions improve considerably in the presence of large voids in the form of krotovinas and cracks in the soil.

4. The data obtained indicate that there is a relationship between the air entry into frozen soil and its water-permeability, depending of moisture conditions. Water-permeability decreases as the rate of air entry through frozen soil decreases.

Received February 18, 1961

BIBLIOGRAPHY

1. BITYUKOV, K. K., M. N. MIKHAYLOV, and V. YA. POPOVA. 1956. Accumulation and conservation of moisture in the soil. 2d. ed. Sel'khozgiz.

2. BOBCHENKO, V. I. 1957. Subsoil irrigation. Sel'khozgiz.

3. VOLKOV, P. S. 1954. Fissuring as a method of wetting soil with surface waters. Gidrotekhn. i melioratiya. No. 11.

4. VORONOV, G. I. 1958. Struggle for the improvement of agriculture and livestock breeding. S. kh. Povolzh'ya. No. 4.

5. KACHINSKIY, N. A. 1927. Soil freezing, thawing, and moisture in winter in the forest and in fields. Moscow.

6. KOMAROV, V. D. 1957. Laboratory investigation of the water-permeability of frozen soil. Tr. Tsentr. in-ta prognozov. No. 54.

7. KUZNIK, I. A. 1954. Certain actual data on the water and physical properties of frozen soils and surface melt-water runoff. Sb. tr. po agron. fiz. No. 7.

8. SREBRYANSKAYA, P. I. 1954. Seasonal freezing and thawing of soils in Central Baraba. Study of the Baraba lowland as an area for agricultural utilization. Tr. Pochv. in-ta im. V. V. Dokuchayeva. Vol. 42.

9. TSYKIN, YE. N. 1956. Water-permeability of frozen soils and its dynamics during snow melting. In: Snow and melt-water. Izd. Akad. Nauk SSSR.

10. SHALABANOV, A. A. 1903. Does frozen soil let water through? Pochvovedeniye. No. 3.

DETERMINATION OF AVAILABLE PHOSPHATES IN PEAT-BOG SOIL

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In peat-bog soils the amount of available phosphates is not only a sign of the degree of phosphorus availability, but also an important index of their general level of fertility (1, 2). However, there is no single adopted method at this time for determining available phosphates in peat-bog soils. Citric acid (1%) and 0.05 N and 0.2 N hydrochloric acid, etc., are commonly used for this purpose. Various investigators (8, 7, 9, 5), also use various soil: solvent ratios. There has been no comparative evaluation of the methods used to this day.

In recent years, in relation to the extensive use of the radioactive isotope of phosphorus in research work, it became possible to give a more reliable comparative evaluation of chemical methods. In particular, Scott-Russel and others (10) compared data of chemical analyses with those obtained by the method of selective absorption by plants. These authors used Larsen's (13) method.

We made it our task to compare the most common chemical methods of determining available phosphates in peat-bog soils, taking as a standard the phosphate content obtained by A. V. Sokolov's (11, 12) isotope method.

Samples of peat-bog soils, differing in the time they were under agricultural use and in their level of fertility, were taken from the plowed layer (0-30 cm) at the following sites:

I. "Vedrich" sovkhoz, Gomel' Oblast'. Plot 1, under agricultural use for 30 years, with highly cultivated soil. Plots 2 and 3, moderately cultivated, under agricultural use for less than 20 years. All three fields consist of wood sedge peat with a degree of decomposition of about 45%.

II. Minsk Experimental Farm of the Belorussian Scientific-Research Institute of Melioration and Water Economy. Plot 4. Reservation drained more than 40 years ago; has not been under agricultural use; slightly cultivated soil. Plot 5, under agricultural use for more than 30 years, with highly cultivated soil, Plot 6, under agricultural use for more than 45 years, with highly cultivated soil. All fields consist of wood-sedge peat of a degree of decomposition of about 45%.

III. "Sloust'" Experimental Plot, Zhdanov kolkhoz, Minsk Oblast'. Plot 7, under agricultural use for 2 years during which no mineral fertilizers were used. Plot 8, same, $P_{30}K_{90}$ were added annually. Plot 9, same, with $P_{60}K_{90}$ added annually. All the plots were drained in 1955. The soil is slightly cultivated and consists of sedge peat with a degree of decomposition of about 40%.

IV. Kossovo Experimental Bog Station, Brest Oblast', Ivatsevich rayon. Samples were taken during an experiment with various amounts of fertilizers added during crop rotation from plots having received in 4 years: $P_{190}K_{430}$ (Plot 10); $P_{235}K_{520}$ (Plot 11); $P_{190}K_{385}$ (Plot 12); and $P_{117}K_{260}$ (Plot 13). All soils are moderately cultivated and had been under agricultural use for about 20 years. They consist of sedge wood peat with a degree of decomposition of about 45%.

The studies were made from 1958-1959. In the first stage of the study soil from Plot 4, at the reseservation of the Minsk Experimental Farm, was used to solve a number of methodological problems.

The total amount of available phosphates was determined by special pot experiments using a radioactive tracer. Ten ml of NaH_2PO_4 solution with P^{32} with a radioactivity of 100 microcuries and a total content of 0.248 mg of P_2O_5 in the 10 ml solution was added to each pot, containing 1.275 kg of absolutely dry soil. This could not have affected neither the phosphate nutrition of plants nor the content of available phosphates in the soil. Each pot received 600 mg of K_2O (in the form of KCl) and 170 mg of N (in the form of NH_4NO_3). The plant tested was barley, strain 485. The experiments were replicated 10 times.

At the end of the experiment the tops and the roots were assessed. Later the individual parts of plants (grain, straw, chaff, roots) were analyzed chemically for total phosphorus and their total radioactivity was determined. The total removal of phosphorus by plants in one pot and the P^{32} content in the harvest were calculated on the basis of the data obtained. The utilization coefficient of P^{32} was determined from the ratio between the P^{32} content in the harvest and the amount of tagged phosphorus added to the pot.

The total content of available phosphorus in the soil was calculated by the formula

$$x = \frac{P \times 100}{K},$$

where $\underline{P}$ is the total content of phosphorus in the entire mass of plants in mg P_2O_5 per pot.

Knowing the weight of the soil in the pot, we can calculate the amount of phosphorus available to plants in mg P_2O_5 per 100 g of absolutely dry soil, which for the given sample (reservation at the Minsk Experimental Farm) was 24 mg P_2O_5.

As solvents for extraction of phosphorus we used: 1) 0.5 N acetic acid; 2) a universal 0.5 N acetate-buffer solvent, by titration for total acidity at pH 4.8; 3) 1% citric acid; 4) 0.2 N hydrochloric acid; 5) 0.05 N hydrochloric acid; and 6) water.

We studied phosphates in 10 g samples of absolutely dry soil. The following soil to solvent ratios were used in the experiments: 1:25, 1:50, and 1:100. The soil sample was shaken for 1 hour and allowed to settle for 16 hours. After filtration through a folded filter with a white wrapping 50 ml of filtrate of acetic acid, acetate-buffer, 0.2 N hydrochloric acid and 1% citric acid and 100 ml of 0.05 hydrochloric acid, and water extracts were taken for the determination of phosphorus. The filtrate was evaporated on a water bath while at the same time 5 ml of concentrated HNO_3 (to oxidize organic phosphates) was added. The precipitate was twice treated with 4 ml of a mixture of concentrated hydrochloric and nitric acid (at a ratio of 3:1) and then treated twice (evaporated) with concentrated HCl (2 ml each time) for conversion into chlorides. Thereafter the precipitate was dissolved in 10 ml of hot 10% HCl. The solution obtained was filtered into a 100-ml flask and the filtrate was then washed with hot water. The filtrate and the washings were brought to 100 ml after cooling.

When phosphorus was determined in the citric extract, the precipitate was additionally ignited for 10 min in order to decompose the citric acid which interferes with the colorimetric determination of phosphorus (4).

The Warren and Pugh method (3) was used to separate iron from all the extracts of peat-bog soils, since specially conducted investigations have shown that iron interfers with the appearance of the blue color, as a result of which the amount of phosphates being determined decreases by 40%-50%.[1]

Table 1

Content of available phosphorus in various extracts. Data in mg P_2O_5 per 100 g of absolutely-dry soil (sample from Plot 4, reservation of the Minsk Experimental Farm)

Extract	Ratio of soil sample to solvent		
	1 : 100	1 : 50	1 : 25
Water	1,3	1,2	1,7
Acetic acid	10,6	5,1	3,4
Acetate-buffer	25,8	9,6	6,5
Citric acid	39,8	26,8	18,1
Hydrochloric acid, 0.2 N	28,0	17,0	9,1
" " 0.5 N	9,5	4,9	2,4

Note: Comma represents decimal point.

Phosphates were determined colorimetrically using the modification method of Schmuck Kurilo, neutralizing the solutions by β-dinitrophenol,

Samples of air-dry peat with a moisture content of 12%-14% were taken for chemical analysis. When determining phosphorus in peat samples with a natural moisture content (50%-60%) the amount of available phosphates found in the extracts was 30%-35% smaller.

Results of the Investigations

The use of various solvents and various soil to solution ratios results in the extracting of unequal amounts of available phosphorus, as it can be seen in Table 1.

As was to be expected, the amount of extracted phosphates increases with increasing soil to solvent ratio. The best agreement with the data from pot experiments (using a radioactive tracer — 24 mg P_2O_5 per 100 g of absolutely dry soil) was obtained when using 0.2 N HCl and 1% citric acid (1:50 ratio) as solvents. Proceeding from this, phosphorus was extracted from all the remaining peat-bog soils with 1% citric acid, and 0.2 N and 0.05 N hydrochloric acid (the latter solvent is widely used by a number of investigators). The soil to solvent ratio in all the experiments was 1:50.

The amount of available phosphates in all the soils studied was also determined in pot experiments using a radioactive tracer. These experiments were replicated 6 times on barley. The assessment made showed that the plant yields are in direct relationship with the amount of available phosphorus in the soils, which had already been shown by earlier investigations (5).

The results of calculations of the amounts of available phosphates according to pot-experiment data and chemical analysis are presented in Table 2, from which it follows that the results closest to those of pot experiments were obtained by extracting phosphates with 0.2 N hydrochloric acid. Data obtained with 0.05 N hydrochloric acid gave low results for the

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[1] At the present time the combersome operation of removing iron, which interfers with the determination of phosphorus, is successfully being replaced in certain laboratories by adding to the extract several milliliters of a hydrochloric solution of hydroxylamine, which changes iron oxide to ferrous iron.

Table 2

Results of the determination of available phosphates in peat-bog soils by means of various methods (data in mg P_2O_5 per 100 g of absolutely-dry soil)

Site and soil	Chemical methods			Data from pot experiments using P^{32}
	1% citric acid	0.2 n HC	0.5 n HCl	
"Vedrich", well cultivated	78	78	20,2	24
Same, moderately cultivated	39	39	5,0	23
Same	51	41	8,6	26
Minsk, slightly cultivated	27	17	4,9	24
Same, well cultivated	76	76	25,1	30
Same	86	83	23,7	31
"Sloust'", slightly cultivated	17	12	1,3	13
Same	16	12	1,9	14
"	19	13	2,0	17
Kossovo, moderately cultivated	34	23	4,7	21
Same	36	27	5,3	24
"	36	27	5,8	22
"	31	26	5,0	19

Note: Comma represents decimal point.

Table 3

Phosphorus content in peat-bog soils of varying degrees of cultivation

Sampling site	mg P_2O_5 per 100 g of absolutely-dry soil			Data from P^{32}, % of 0.2 N HCl	Avail. P_2O_5 in the pl. layer, kg/ha, accrd. to data from chemical analysis (0.2 N HCl)	P_2O_5 taken up by plants		P_2O_5 taken up by plants in % of available
	Total	Extracted with 0.2 N HCl	Accrd. to data from the radioactive tracer (P^{32}, pot experimt.)			mg/pot[a]	kg/ha[b]	
Highly cultivated								
"Verdrich"	354	78	24	31	468	239	114	20
Minsk	318	76	30	39	456	205	98	22
Same	350	83	31	38	498	212	101	20
More than average cultivated								
"Vedrich"	232	39	23	59	234	146	70	30
Same	300	41	26	62	246	154	74	30
Moderately cultivated								
Kossovo	262	23	21	93	138	156	74	54
Same	264	27	24	87	162	161	77	47
"	271	27	22	82	162	158	76	47
"	282	26	19	73	156	138	66	42
Slightly cultivated								
Minsk	226	17	24	141	102	46	22	22
"Sloust'"	197	12	13	111	72	25	12	17
Same	200	13	14	111	78	27	13	17
"	198	13	17	131	78	28	14	17

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[a] In the experiment each pot contained 1275 g of absolutely dry soil.

[b] The weight of the plowed horizon in 1 ha of peat-bog soil was conditionally taken as 600,000 kg.

majority of soils, while when 1% citric acid was used the results were too high.

The best agreement between the results obtained with 0.2 N HCl and the radioactive tracer method was found for slightly and moderately cultivated peat-bog soils. This is more clearly demonstrated by the data in Table 3.

The largest amount of total phosphorus (320-250 mg P_2O_5 per 100 g of soil) was found in all the highly cultivated peat-bog soils, which is attributable to the accumulation of phosphates as the expense of fertilizers added in the previous years. The maximum amount of available phosphorus, determined chemically, is 80 mg P_2O_5 per 100 g of soil, which is about 500 kg/ha P_2O_5 when reduced to the 30 cm thick plowed layer. The amount of available phosphorus in these soils as determined by the isotope tracer method showed an amount of phosphates to be 24-31 mg P_2O_5 per 100 g of soil, i. e., 2.5-3 times less than obtained chemically.

The content of total phosphorus decreases to 260-300 mg P_2O_5 per 100 g of soil and that of available phosphorus in 0.2 N HCl to 23-26 mg P_2O_5 per 100 g of soil for moderately cultivated soil, which amounts to 140-160 kg/ha of P_2O_5 in the 30 cm thick plowed layer. Data obtained by the isotope tracer method are similar to the foregoing: 19-23 mg P_2O_5 per 100 g of soil, or 73%-93% of the amount of phosphorus determined chemically.

Rather interesting results were obtained for slightly cultivated soils. The amount of available phosphates in 0.2 N HCl proved to be lower in this case than that obtained by the isotope tracer method (it exceeded the results of chemical determination by 10%-40%). The results obtained can be explained if we consider that the chemical method makes it possible to determine the amount of phosphorus after a short treatment with the solvent, whereas when growing plants (as in the isotope tracer method) the latter act on the soil for a long period of time.

Table 3 presents an approximate calculation of the use of available phosphates by plants based on data on the extraction of phosphorus by the total yields. This calculation showed that barley took up about 20% of available phosphorus from highly cultivated soils containing up to 500 kg/ha P_2O_5. In moderately cultivated soils plants absorb about 50% of the available phosphates. As far as slightly cultivated soils are concerned the phosphorus uptake by plants drops to 16%-20% of the total amount of available phosphorus. Consequently, the available phosphates contained in small amounts in such soils are relatively little utilized by plants.

The data obtained are of interest in relation to the problem of the degree of availability of phosphorus to plants in peat-bog soils.

As we know, when characterizing sod-podzolic soils by the Kirsanov method, soils containing less than 5 mg P_2O_5 per 100 g of soil are classified as low supply of phosphates; those containing 10-15 mg P_2O_5 per 100 g of soil, as medium supply of phosphates; and those containing more than 20 mg P_2O_5 per 100 g of soil, as high supply of phosphate. These gradations are unsuitable for peat-bog soils. Soils containing less than 50 kg/ha P_2O_5 in the plowed layer according to the data obtained with 1% citric acid extracts, are classified by Lebedevich (6) as low supply of phosphates, while soils containing more than 500 kg/ha P_2O_5 are classified as high supply of phosphates. We believe on the basis of the data obtained that in order to characterize the productivity of peat-bog soils the following degree of phosphate availability should be used:

a) soils containing less than 20 mg P_2O_5 per 100 g of absolutely dry soil in the 0.2 N HCl solution are very poor in phosphorus. The total amount of available phosphates in the plowed layer of 1 ha is about 120 kg P_2O_5. Under these conditions it is expedient to use larger amounts of phosphorus fertilizers than those usually added to peat-bog soils;

b) soils containing from 20-40 mg P_2O_5 per 100 g of soil have a medium supply of phosphates, having from 120-240 kg P_2O_5 in the plowed layer of 1 ha.

c) soils containing from 40-60 mg P_2O_5 per 100 g of soil are supplied with a more than average amount of phosphates. They contain 240-360 kg of available phosphates in the plowed layer of 1 ha.

d) soils containing more than 60 mg P_2O_5 per 100 g of soil are well-supplied with phosphates and require the least addition of phosphorous fertilizers.

The foregoing gradations can be recommended for the differential use of phosphorous fertilizers on peat-bog soils, depending on soil conditions. The results of field experiments bear witness to the fact that on old plowed peat-bog soils with a high content of available phosphates plants which require increased amounts of fertilizer (potatoes, sugar beet) produce somewhat more, while the yield of grain crops sometimes even

Table 4

Corn yield on soils cultivated to various degrees in kg per 10 m²

Amount of fertilizer	Recently-reclaimed soil —bog massif "Sloust'"		Old plowed soil, Minsk Experimental Farm	
	kg	%	kg	%
Without fertilizers	8,7	100	61,0	100
P_{60}	22,9	224	69,0	113
P_{90}	26,2	300	72,6	119
K_{90}	9,1	104	80,1	131
K_{120}	9,1	104	89,9	147
$P_{60}K_{120}$	56,0	643	97,0	159
$P_{90}K_{90}$	63,0	725	96,2	158

Note: Comma represents decimal point.

decreases when the amounts of phosphorous fertilizers are increased on such soils. In recently-reclaimed soils, poor in available phosphates, increased amounts of phosphorous fertilizers have a positive effect on the majority of agricultural crops. As an illustration of the varying effectiveness of phosphorous fertilizers on recently-reclaimed and old plowed peat-bog soils, Table 4 shows the results of two field experiments with corn.

The addition of phosphates to recently-reclaimed soils increased the corn yield 2-3 times, whereas on old plowed soils the increment was only 13%-19%.

Conclusions

1. It is recommended that 0.2 N hydrochloric acid at a soil to solvent ratio of 1:50 be used for determining available phosphorous in peat-bog soils. The article describes briefly the method of determining available phosphorus in the soils studied which gives results agreeing best with the results of pot experiments using an isotope tracer for soils medium and well-supplied with phosphates.

2. It is recommended that the following gradations for the availability of phosphates be used to characterize the requirement of peat-bog soils for phosphoric acid fertilizers when growing agricultural crops:

a) soils with low supply of phosphates, having less than 20 mg P_2O_5 per 100 g of soil, required increased amounts of phosphorous fertilizers;

b) soils with medium supply of phosphates, containing 20-40 mg P_2O_5 per 100 g of soil, required the usual amounts of phosphorous fertilizers;

c) soils with a more than average supply of phosphates, having 40-60 mg P_2O_5 per 100 g of soil, required reduced amounts of phosphorous fertilizers, or the fertilizers was not needed every year;

d) soils well-provided with phosphates, containing more than 60 mg P_2O_5 per 100 g of soil, required reduced amounts of phosphorous fertilizers and only for especially demanding crops (corn, sugar beet, potatoes) in combination with potassium and nitrogen fertilizers.

Received August 26, 1960

BIBLIOGRAPHY

1. BEL'SKIY, B. B. 1958. Importance of fertilizers in the increased yields and the economical effectiveness of their use on peat-bog soils. Tr. In-ta melior., vodn. i bolotn. kh-va. Vol. 8.
2. BEL'SKIY, B. B. and T. N. KULAKOVSKAYA. 1957. Role of fertilizers in the cultivation of newly-reclaimed peat-bog soils. In the collection: Reclamation of virgin land in the non-chernozem belt. Sel'khozgiz, Leningrad.
3. GEDROYTS, K. K. 1955. Collected works. Vol. 2. Moscow.
4. GINZBURG, K. YE. 1952. Colorimetric determination of phosphoric acid in citric acid extracts. Pochvovedeniye. No. 12.
5. KULAKOVSKAYA, T. N. 1956. Influence of mineral fertilizers on the cultivation of peat-bog soils. Tr. In-ta melior., vodn. i bolotn. kh-va. Vol. 7. Minsk.
6. LEBEDEVICH, N. F. 1951. Principles of the grass-arable system of agriculture on peat soils. Gosizdat BSSR, Minsk.
7. LUPINOVICH, I. S. and T. F. GOLUB. 1958. Peat-bog soils of the BSSR and their fertility. Izd. Akad. Nauk BSSR.
8. NIKONOV, M. N. et al. 1956. Agricultural-chemical characterization of peats in relation to their agricultural utilization. Collection of articles on the study of peat deposits. Sel'khozgiz, Moscow.
9. REKHT, S. A. 1935. Dynamics of nitrogen and of phosphorus taken up by roots in relation to the duration of bog cultivation. Problem of the chemical treatment of bog soils. Izd. VASKhNIL.
10. SCOTT-RUSSEL, et al. 1958. Factors affecting the availability of soil phosphates to plants. In: Materials of the International Conference on the Peaceful Uses of Atomic Energy. Vol. 12. Sel'khozgiz.
11. SOKOLOV, A. V. 1958. Amount of available phosphates in soils and their accumulation during the addition of phosphorous fertilizers. Pochvovedeniye No. 2.
12. SOKOLOV, A. V. 1958. Determination of the availability of soil phosphates and fertilizers by means of the radioactive phosphorus isotope. Material of the International Conference on the Peaceful Uses of Atomic Energy. Vol. 12. Sel'khozgiz.
13. LARSEN, S. 1952. The use of P^{32} in studies of the uptake of phosphorus by plants. Plant and Soil. 4(1):1-40. (Cited from Scott-Russel [10]).

INFLUENCE OF SOIL CONDITIONS ON THE HYDROLOGICAL EFFECT OF DRAINAGE

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The present paper examines certain characteristics of the hydrological effect of drainage, depending on soil conditions. To study this problem we used the material of field investigations on the drainage discharge regime and the ground water level regime at the experimental drainage system in Vil'yams kolkhoz, Orgre rayon (8). The soils of the experimental field are sod-podzolic and sod-podzolic gley sandy loams and clay loams (coarse). These soils are the most widespread in Latvia, occupying 57.7% of the entire territory of the republic (10). They suffer, as a rule, from excess moisture. As we can see from Table 1, the sod-podzolic and sod-podzolic-gley soils in our experiment differ little in their particle-size composition, bulk density, and porosity. However, as a result of gleyization, the filtration coefficient of the subplow horizon of sod-podzolic-gley soils is 2-3 times lower than the corresponding coefficient in sod-podzolic soils. The filtration coefficient was determined by the method of water renewal in a borehole (Fig. 1) and calculated by the Donat formula (11, 12)

$$K = 16.3\,\frac{r^2}{Ht}\,\log\frac{y_1 - h}{y - h}\ \text{(cm/sec)},$$

where r is the radius of the borehole (cm); h is the depth of the water table from the soil surface prior to discharge (cm); H is the depth of the water in the borehole prior to its discharge (cm); H + h = T is the depth of the borehole (cm);

Table 1

Certain average data on the physical properties of soils in plots of the experimental drainage in Vil'yams kolkhoz

Horizon		Particle-size composition, %								Specific gravity	Bulk density, g/cm³	Porosity, %	In filtration coefficient K, cm/sec
		Particle diameter, mm							Designation of soil texture (N. A. Kachinskiy)				
Designation	Depth, cm	1—0,25	0,25—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001	<0,01					
Sod-podzolic soil													
A_1	0—22	10,62	57,62	16,65	4,79	5,89	4,42	15,11	Sandy loam	2,62	1,21	53,8	0,001÷ ÷0,005
A_2	22—30	11,53	55,56	15,65	5,17	6,75	5,34	17,26	"	2,57	1,39	45,9	
B	30—88	10,74	48,64	13,86	3,69	5,52	17,55	26,76	Coarse cl. loam	2,63	1,47	44,1	
C	88—140	10,92	50,46	13,81	4,10	5,71	15,00	24,81	"	2,66	1,51	43,[illegible]	
Sod-podzolic-gley soil													
A_1	0—26	7,81	40,58	35,83	5,55	6,87	3,36	15,78	Sandy loam	2,54	1,26	50,3	0,0008÷ ÷0,002
B_1/g	26—56	11,65	59,20	10,51	5,12	7,59	5,93	18,64	"	2,69	1,43	46,8	
B_2/g	56—110	11,68	42,46	21,49	4,28	10,37	9,72	24,37	Coarse cl. loam	2,61	1,50	42,5	
C/g	110—140	16,31	49,26	18,32	3,08	8,03	5,00	16,11	"	2,68	1,48	44,7	

Note: Comma represents decimal point.

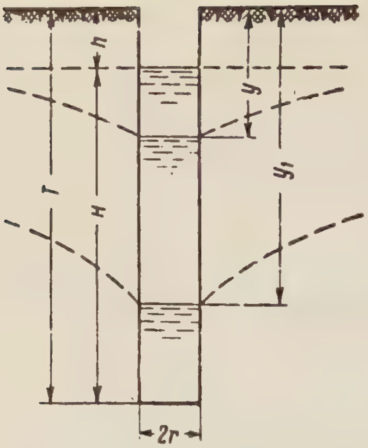

Fig. 1. - Schematic diagram for determining the filtration coefficients according to the Donat formula.

y_1 is the depth of the water table from the soil surface after discharge (cm); y is the depth of the water table from the soil surface after a certain time t (cm); and t is the time during which the water level in the borehole rises from y_1 to y (sec).

1. Ground Water Level Regime

To study the effect of soil conditions on the ground water level regime we constructed duration (expectancy) curves of ground water levels for drainage systems A-4 and A-5, located on sod-podzolic soils, as well as for drainage systems C-2 and C-3 in sod-podzolic-gley soils. A series of statistical characteristics of the level regime, obtained from water level duration curves is presented in Table 2. From Figure 2 and Table 2 it follows that:

1. At one and the same drain (t) depths and distances between drains (E) the effectiveness of drainage regulation of the water level regime is considerably greater in sod-podzolic soils than in sod-podzolic-gley soils. For instance, in the hydrological years from 1957-1958 and 1958-1959 the water stood at a level of 0-50 cm (T_{0-50}) for 76 days in drainage system A-5 (30 x 0.9) in sod-podzolic soils, while in drainage system C-3 (30 x 0.9) in sod-podzolic-gley soil it stood 197 days, i. e., 121 days longer. At 25% expectancy (H_p = 25%) the water table in system A-5 was 54 cm, while in system C-3 it was only 21 cm.

2. The regulation of the water level regime by drainage in sod-podzolic soil with a distance of E = 30 m (A-5) between drains is more intense than in sod-podzolic-gley soils with E = 20 m (C-2). For instance, T_{0-50} averaged 136 days during the period of investigation in system C-2 (20 x 0.9), while it averaged only 76 days in system A-5.

3. The reduction of the distance between drains E from 30 to 20 m in sod-podzolic-gley soils (systems C-3 and C-2) had a greater effect on the water level regime than the same

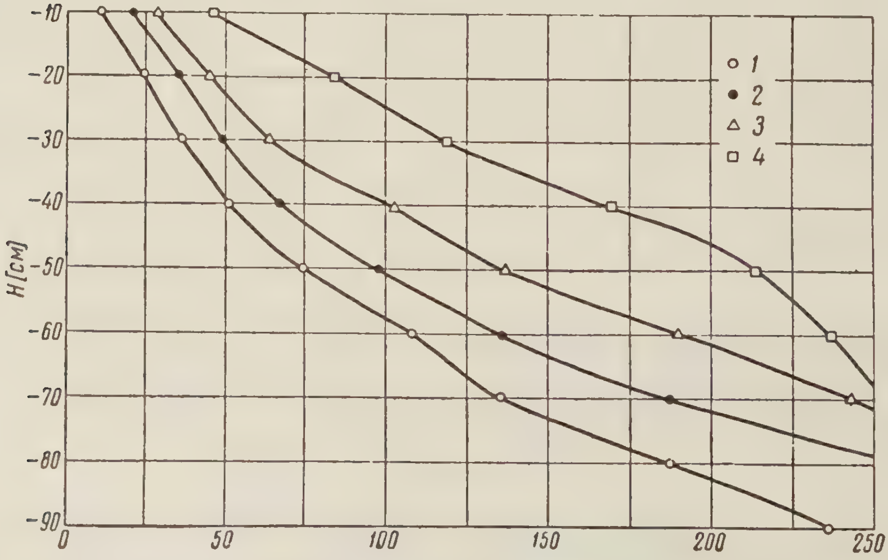

Fig. 2. - Duration (expectancy) curves of ground water levels for various drainage systems.
1 - A = 4 (20 x 0.9); 2 - A = 5 (30 x 0.9); 3 - C = 2 (20 x 0.9); 4 - C = 3 (30 x 0.9) for the hydrological year of 1957-1958.

reduction in E in sod-podzolic soils (systems A-4 and A-5). For instance, when E in sod-podzolic soils was reduced from 30 to 20 m, the duration of the flooding of the plowed layer decreased on the average from 27 to 18 days, i. e., 9 days, while in sod-podzolic-gley soils it decreased from 85 to 42 days, i. e., by 43 days.

2. Drainage Discharge Regime

Studies of the drainage discharge regime show that maximum drainage discharge moduli in sod-podzolic-gley soils. Thus, for instance, during the period of operation of the drainage from February 13, 1958, to March 5, 1958, the maximum modulus of drainage discharge in system A-5 in sod-podzolic soils was q = 0.88 liter/sec-ha, while in the corresponding system in sod-podzolic-gley soils (C-3) q = 0.61 liter/sec-ha. It must be noted that drainage discharge in sod-podzolic-gley soils lags somewhat behind that in sod-podzolic soils.

Figure 3 — shows expectancy curves of mean daily drainage discharge moduli for drainage systems A-4 (20 x 0.9) and C-2 (one hydrological year is taken as a basis for expectancy). From Fig. 2 and Table 3 it follows that at expectancy p = 3% the drainage discharge moduli q in sod-podzolic soils are considerably higher than the corresponding moduli q in sod-podzolic-gley soil at the same expectancy. For instance, in the hydrological year of 1957-1958 q = 1.11 liter/sec-ha in system A-4 at expectancy p = 1%, while in system C-2 q = 0.72 liter/sec-ha. It is characteristic that the moduli q for the systems in sod-podzolic soils differ the more the smaller is the expectancy p%. This means that the highest drainage discharge moduli differ most sharply for these systems.

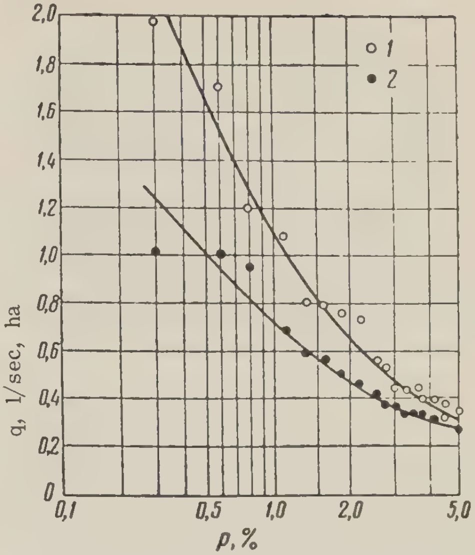

Fig. 3. - Expectancy curves for drainage discharge moduli of various drainage systems. 1 - A = 4 (20 x 0.9); 2 - C = 2 (20 x 0.9). Hydrological year of 1958-1959

The investigations show that maximum q in sod-podzolic-gley soils is more than five times higher and that in sod-podzolic soils more than 10 times higher than the design drainage discharge modulus (9). The latter is usually taken as 0.5-0.7 liter/sec-ha. The plowed layer and the fill of drainage ditches play an active role in the formation of maximum drainage discharge.

3. Interaction Between Drainage Discharge and Ground Water Pressure

In order to analyze simultaneously the drainage

Table 2

Statistical characteristics of the ground water level regime, average for the hydrological years 1957-1958 and 1958-1959 for various experimental drainage systems in Vil'yams kolkhoz

Drainage system			Time of stagnation of the water level at a depth (in days), cm			Depth of the stagnation of water levels (cm) at various expectancies, %		
Designation	Distance between drains E, m	Drain depth, t, m	0—20 T_{0-20}	0—50 T_{0-50}	0—90 T_{0-90}	$H_{p=50\%}$, см	$H_{p=25\%}$ см	$H_{p=10\%}$ см
Sod-podzolic soil								
A-4	20	0,9	19	69	203	84	62	33
A-5	30	0,9	27	76	255	74	54	27
Sod-podzolic-gley soil								
C-2	20	0,9	42	136	264	60	39	17
C-3	30	0,9	85	197	259	58	21	10

Note: Comma represents decimal point.

discharge regime and the ground water level regime, according to the known method (3, 4, 7), we constructed curves of the relationship between ground water pressure (y) and the drainage discharge modulus (q), or so-called drainage discharge modulus curves q = f (y) (in irregular terrain y; the strip between the drain is determined by the depth of the drain conduit). The drainage discharge modulus curves were used to construct averaged depression curves for various constant values of drainage discharge (7). Examples of such curves are given Fig. 4. From the figure it follows that the depression curve for sod-podzolic soils (system A-5) is more curved and that for sod-podzolic-gley soils (system C-3) is flatter. The latter depression curves has a sharp break near the drain.

The form of the depression curve can be characterized by the depression coefficient φ. The investigations show that with the same degree of drainage, the depression coefficient in sod-podzolic-gley soils is always higher than in sod-podzolic soils. We found that in fields with shallow drainage the depression coefficient in sod-podzolic soils during the falling phase of the cycle of drainage operation varies on the average from φ = 0.74-0.86, while in sod-podzolic-gley soils φ = 0.88-0.94, depending on the distance between drains. This difference is somewhat smaller during the rising phase of the cycle of drainage operation. In sod-podzolic soils it averages φ = 0.81-0.97, and in sod-podzolic-gley soils, φ = 0.91-0.98.

Analysis of the depression curves shows that at q = 0.10-0.15 liter/sec-ha the depression curve in sod-podzolic-gley soils is located at the height of the plowed-subplow layer, or close to it, while at q = 0.3-0.4 liter/sec-ha the plowed layer is usually completely flooded. However, in sod-podzolic soils moduli up to 1.0 liter/sec-ha may form when the depression curve is located at a depth of 40 cm and more from the soil surface, depending on the degree of drainage, the phase of the cycle of drainage operation, and other conditions.

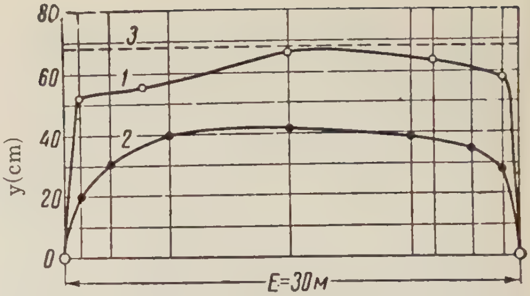

Fig. 4. - Average depression curves at $\frac{dq}{dt}$ 0 for drainage system.
1 - A = 50 (30 x 0.9); 2 - C = 3 (30 x 0.9). Cycle (period) of effective drainage from May 5 to 15, 1958; 3 - plowed-subplowed horizon.

The plowed layer usually participates actively in the formation of drainage discharge in sod-podzolic-gley soils at q $\geq$ 0.2 liter/sec-ha, and in sod-podzolic soils at q $\geq$ 1.5 liter/sec-ha.

In sod-podzolic-gley soils the initial ground water pressure, i. e., the minimum pressure at which drainage discharge begins, is several times higher than in sod-podzolic soils. In the

Table 3

Expectancy of drainage discharge moduli for various sod-podzolic (A-4 and A-5) and sod-podzolic-gley (C-2 and C-3) soils

Drainage system			Drainage discharge modulus, 1/sec-ha						
			Expectancy, q %						
Designation	Distance between drains, E, m	Drain depth, t, m	0,3	1,0	2,0	3,0	5,0	7,0	10,0
Hydrological year 1957-1958									
A-4	20	0,9	>3,0	>3,0	1,40	0,76	0,55	0,39	0,32
A-5	30	0,9	>3,0	>3,0	1,30	0,69	0,43	0,33	0,29
C-2	20	0,9	>3,0	>3,0	1,20	0,71	0,46	0,35	0,27
C-3	30	0,9	>3,0	>3,0	0,96	0,60	0,40	0,30	0,21
Hydrological year 1958-1959									
A-4	20	0,9	2,20	1,11	0,70	0,50	0,33	0,23	0,15
A-5	30	0,9	1,24	0,84	0,60	0,44	0,30	0,20	0,10
C-2	20	0,9	1,25	0,72	0,48	0,37	0,26	0,21	0,18
C-3	30	0,9	1,24	0,72	0,48	0,38	0,27	0,22	0,16

Note: Comma represents decimal point.

first case the initial pressure is equal to 50-70 cm, while in the second, it is 10-30 cm.

In conclusion we must emphasize that all the main indices of the hydrological effect of drainage in sod-podzolic and sod-podzolic-gley soils differ sharply. In sod-podzolic-gley soils the drying action of systematic drainage is considerably less effective than in sod-podzolic soils. The reason for this is the low infiltration ability of the subplow layers in sod-podzolic-gley soils.

Conclusions

1. At equal drain depths (t) and equal distances between the drains E the intensity of the regulation of the water regime by drains is considerably greater in sod-podzolic soils than in sod-podzolic-gley soils. These soils differ most sharply in the duration of high water levels and in the magnitude of maximum drainage discharge moduli.

2. The maximum drainage discharge modulus (q_{max}) in sod-podzolic-gley soils may exceed 4 liter/sec-ha, while in sod-podzolic soils it is 10 liter/sec-ha. The plowed layer actively participates in the formation of high drainage discharge moduli ($q > 0.3$ liter/sec-ha) in sod-podzolic-gley soils.

3. The minimum ground water pressure at which drainage discharge begins is 10-30 cm in sod-podzolic soils and 50-70 cm in sod-podzolic-gley soils. With the same drainage discharge magnitude the depression curve is much lower in sod-podzolic soils than in sod-podzolic-gley soils.

4. The decrease of the drying effectiveness of systematic drainage in sod-podzolic-gley soils as compared to sod-podzolic soils is attributable to the low infiltration capacity of the subplow layers of gley soils.

Received August 24, 1960

BIBLIOGRAPHY

1. VEDERNIKOV, V. V. 1939. Filtration theory and its application in irrigation and drainage. Gosstroyizdat, Moscow.

2. GOL'DMAN, A. G. 1947. Theory of the water entry into soil. Pochvovedeniye. No. 1.

3. KRIVONOSOV, I. M. 1952. Drainage of slightly water-permeable clay soils. Gidrotekhn. i melioratsiya. No. 10.

4. PISAR'KOV, KH. A. 1939. Design and actual drainage moduli in drainage systems. Gidrotekhnich. sb., SNIIGiM. No. 9.

5. POLYAKOV, B. V. 1946. Hydrological analysis and calculations. Gidrometizdat, Leningrad.

6. ROZOV, L. P. 1937. Soil-dynamic processes in podzolic soils during drainage. Pochvovedeniye, No. 5.

7. SVISLIS, P. B. 1957. Change in the water-infiltration of drained sod-calcareous soils. Collection of papers of the Latvian Scientific-Research Institute of Hydraulics and Melioration.

8. SHKINKIS, TS. N. 1960. Certain investigations on the regulation of the ground water level regime of excessively wet mineral lands by drainage. Izv. Akad. Nauk LatvSSR. No. 8.

9. SHKINKIS, TS. N. 1960. Effect of drainage and stability of drainage systems during floods. Summary of papers presented at the Scientific-Production Conference on the Exploitation of Drainage Systems. Kaunas.

10. BRIVKALNS, K. 1959. Latvijas PSR augsnes. LVI, Riga.

11. UISKA, J. 1958. Drenaza. LVI, Riga.

12. DONAT, J. 1935. Die Saugstangentfernung bei Drähungen in Mineralböden. Wasserwirtschaft und Technik. Wien No. 18-20.

METHODS OF DETERMINING NON-SILICATE AMORPHOUS AND CRYSTALLINE SESQUIOXIDES IN SOILS AND CLAYS

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Iron and aluminum are found in soils in the non-silicate form (free) as components of primary and secondary minerals, in an adsorbed state, in solution, and finally bound to organic substances and organisms.

The determination of non-silicate sesquioxides is of great importance for the solution of a number of genetic and agricultural-chemical problems. The intensity and conditions of soil formation are determined on the basis of the amount of sesquioxides and their distribution in the soil profile. Sesquioxides serve as indicators of the history of soil development and the direction of processes taking place in it. The accumulation of sesquioxides in the illuvial horizon, and the presence of concretionary film, and tongues in the soil indicate the weathering of alumosilicates from which sesquioxides are liberated, as well as the rate and direction of their movement. It follows from the foregoing that in order to study the movement of colloids and clay with (lessivage, illimerization) and without the decomposition of minerals, it is very important to know the amount of sesquioxides and their distribution.

It is well known that sesquioxides absorb phosphoric acid, since they form compounds with them which are not readily soluble. Therefore, the uptake by plants of phosphates added to the soil depends to a considerable degree on the content of non-silicate sesquioxides. Their role is especially evident in red earths, laterites, and podzolic soils. Unfortunately, until recently no attention had been paid during the evaluation of the role of free sesquioxides in the absorption of phosphorus to the fact that sesquioxides occur in amorphous and crystalline forms; at the same time it is of great importance to the physical-chemical properties of soils. For instance, according to our data, amorphous iron hydroxide absorbs 108 times more phosphorus than crystalline iron hydroxide, while amorphous aluminum hydroxide absorbs 137 times more phosphorus than crystalline aluminum hydroxide (2). Before mineralogical analysis methods were used it was very difficult to detect amorphous and crystalline sesquioxides.

At the present time there is no difficulty in determining the crystalline forms of these compounds, using thermal analysis, since they give clear endothermal effects at a temperature of about 300°C. Characteristic diffraction lines on X-ray photographs also show which crystalline mineral are present in a material. The use of the electron microscope for verifying crystallization in such experiments is inadmissible.

We established by means of the thermal and X-ray methods that red earths and laterites contain sesquioxides primarily (but not completely) in the crystalline form, and that podzolic soils contain sesquioxides primarily (but not completely) in the crystalline form, and that podzolic soils contain sesquioxides primarily in the amorphous form (1). Unfortunately, there are no chemical methods for separating these forms.

Sesquioxides are often bound with organic substances in soils. Without touching upon these compounds, we can definitely say that they have a tremendous importance for soil structure.

Investigators have been concerned a long time with the development of methods for determining non-silicate sesquioxides. The most widely accepted methods are those of Tamm (8) and Kirsanov (3), while some investigators also use the methods of Deb (6), Stefanovits (9), and Mehra and Jackson (7) for determining free iron. The foregoing methods were verified by us on minerals and soils.

Because these methods are used in various modifications, we will describe their principles and techniques. One of the purposes of our experiments was to remove sesquioxides from the soil as completely as possible. Therefore, we made three successive extracts using each of these methods. Our second purpose was to follow the conversion of non-silicate sesquioxides from clay minerals extracts. Finally, we tried to establish the differences between the solubility of crystalline and amorphous sesquioxides by means of mineralogical methods (thermal and X-ray).

We used the Tamm method in the following form. Two grams of soil (or mineral) were shaken for one hour with 100 ml of Tamm's reagent, consisting of a mixture of oxalic acid (32.5 g) and ammonium oxalate (62.1 g) per 2.5 liters of water. The pH of the mixture was 3.2. Then the suspension was filtered and the soil was treated with Tamm's reagent for the second time. The soil remaining in the funnel was placed again in the glass and treated for the third time with a fresh portion of Tamm's reagent. After each treatment iron, aluminum, and silica were determined in the extracts by evaporating them and igniting the residue in order to remove ammonium salt. Then the residue was treated with hydrochloric acid, after which silica remained in the residue and iron and aluminum salts in the solution. Silica was determined by the usual weighing method. Iron was precipitated in the hydrochloric acid with copperon ($C_6H_5N(NO)ONH_4$) and determined by the weighing method. The aluminum remaining in the solution was also precipitated with cupferron after neutralization with ammonia (bromothymol blue indicator) and determined by the weighing method.

The Kirsanov method uses 0.2 N hydrochloric acid with a liquid to solid ratio of 10 to dissolve sesquioxides. The interaction time is 24 hours. Iron in filtrate was determined with Trilon B, while the total amount of sesquioxides was determined by the weighing method after precipitation with ammonia. The iron and aluminum contents were determined by difference. Silica was not determined by the Kirsanov method.

The Stefanovits method uses an aqueous solution of complexione, containing potassium chloride, as a solvent for sesquioxides. Soil samples of 5 g are taken for analysis and after the soil is sifted through a sieve with openings 0.2 mm in diameter it is placed in a 400 ml beaker. Fifty milliliters of a 0.1 N solution of complexone, containing potassium chloride, are added to the beaker. The suspension is boiled for three minutes and then the soil is placed on a filter and washed five times with a 0.1 N solution of potassium chloride. Ten milliliters of the solution are used for each washing. The filtrate is evaporated and the precipitate is heated in a muffle in order to decompose the trilon and iron complex. The ignited precipitate, consisting of sesquioxides, is dissolved in 5% hydrochloric acid and then precipitated with ammonia. Iron is determined trilonometrically.

The Deb method is recommended only for determining non-silicate iron. Sodium hydrosulfite ($Na_2S_2O_4 \times 2H_2O$) is used as the solvent. Fifty milliliters of water are added to a 1-0.25 g sample in a 100 ml flask and the suspension is thoroughly shaken. Then 2 g of sodium hydrosulfite are added to the suspension, the flask is placed in a bath heated at 40°C and kept there until the solution becomes colorless, which requires that the flask be shaken periodically. After this, the suspension is filtered and persulfate of ammonia is added to the filtrate in order to convert bivalent iron to trivalent iron, which is then determined trilonometrically.

Mehra and Jackson's method differs slightly from the Deb method, even though the main reagent is the same. In this method 40 ml of a 0.3 N solution of sodium citrate and 5 ml of 0.1 N sodium bicarbonate are added to 4 g of soil. The mixture is heated in a water bath to 80°C, 1 g of dry $Na_2S_2O_4$ is added to it, and the whole content is shaken for one minute, and then periodically for 15 minutes. At the end of the 15 minute treatment 10 ml of concentrated sodium chloride and 10 ml of acetone are added to accelerate the formation of the flocculent precipitate. After the suspension is stirred it is heated in a water bath and filtered into a graduated flask, and then iron, aluminum, and silica are determined in the individual portions. In order to extract completely sesquioxides the author recommends that three successive extracts be made. Aluminum is determined in the extracts from the difference between the weight of the sesquioxide precipitate and the amount of iron determined trilonometrically. Silica is determined by the weighing method. The authors of the method maintain that not only amorphous, but also crystalline forms of sesquioxide can be determined by this method. Our experiments do not confirm this. We found that only a large part of goethite and gibbsite enters the solution.

The majority of the methods suggested for determining free sesquioxides do not take into account their crystallinity, while at the same time this factor has an important effect on solubility. Therefore, in selecting the material for investigation we took clay minerals, as well as artificially prepared iron and aluminum hydroxides in amorphous and crystalline forms in addition to soils. Amorphous iron hydroxide was prepared from its chloride, while amorphous aluminum hydroxide was prepared from its sulfate by precipitation with ammonia and subsequent washing from impurities. In order to convince ourselves that our material was amorphous, we verified it by means of X-ray and thermographic methods. The absence of diffraction lines on the X-ray photograph and of thermal effects near 300°C on the thermograms served as an objective proof of amorphism. It is well known that sesquioxides crystallize on drying and heating, but not always (1). We used this fact to obtain crystalline forms. To do this, freshly-prepared iron and aluminum hydroxides were dried for 15 days and heated at 50°-60°C.

Since red earths and laterites primarily, but not completely, contain crystalline sesquioxides (goethite and gibbsite), we also used these materials in our experiments. Thermograms (Fig. 1) clearly show the endothermal effects near 300°C, indicating the presence in these soils of crystalline sesquioxides — goethite and gibbsite. We used bauxite for the same reasons.

We also studied the major clay minerals found in soils and containing sesquioxides as a component of the crystal lattice or as an admixture. Table 1 shows the total chemical composition of these materials, while Figure 1 gives their thermograms. We do not include their X-ray description.

Let us examine the data on the solubility of iron and aluminum hydroxides, isolated from soil. As we can see from Table 2, none of the reagents used can dissolve even amorphous sesquioxides in one treatment, crystalline sesquioxides is not included here, even though the first extraction dissolved more readily than the latter. Exactly 45.9% amorphous iron hydroxide and 68.6% amorphous aluminum hydroxide passed into the first extract with Tamm's reagent.

Table 1

Total chemical composition of minerals and soils, % of ignited sample

Material studied and depth, cm	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	$\frac{SiO_2}{R_2O_3}$
Montomorillonite (askanite), Georgia	64,7	20,8	5,0	2,0	5,7	0,64	1,75	4,5
Halloysite, Czechoslovakia	53,4	40,9	1,90	0,17	0,09	0,02	0,015	2,24
Muscovite, Karelia	52,5	29,5	3,77	0,80	1,59	8,95	0,86	2,70
Kaolinite, Pologi, particles <0.001 mm in diameter	51,2	46,4	1,6	0,24	0,39	0,10	0,03	1,83
Red earth, Chakva, Profile 154 (5-15)	41,7	33,2	19,3	0,80	1,87	0,51	0,32	1,53
Same (30-40)	36,6	33,7	23,8	0,63	2,00	0,15	0,11	1,27
" (150-160)	39,3	34,2	22,9	0,62	2,30	0,25	0,11	1,38
Laterite, Vietnam, Profile 273 (50-60)	35,5	32,0	28,0	0,28	0,33	0,05	0,02	1,19
Strongly podzolic soil, Smolensk Oblast', Profile 6 (74-87)	78,6	12,2	2,64	1,07	0,56	1,47	0,68	10,3

Note: Comma represents decimal point.

After being crystallized the same hydroxides dissolved several times less. For instance, there was only 7.34% iron hydroxide and 0.34% aluminum hydroxide in the solution.

From the same table we can see that hydrochloric acid and trilon B dissolve much less amorphous sesquioxides than Tamm's reagent. Sodium hydrosulfite is similar in its action to Tamm's reagent; unfortunately it was used only to determine mobile iron, but not aluminum. The solubility of sesquioxides is much greater when three successive extracts are made. In this case amorphous hydroxides dissolve almost completely in Tamm's reagent, while iron is almost completely dissolved in sodium hydrosulfite. Hydrochloric acid occupies an intermediate place as a solvent, while trilon B occupies the last place.

However, crystalline sesquioxides entered solution in only small amounts, even after three extractions. After three Tamm extractions, only 15% of iron dissolved and considerably less aluminum. After a threefold treatment, sodium hydrosulfite dissolved 33% of crystalline iron hydroxide, i. e., more than Tamm's reagent. The other reagents, such as hydrochloric acid and trilon B, dissolved less amounts of sesquioxides.

Even less amounts of sesquioxides enter solution if they are components of clay minerals. This can be seen from Table 3. Threefold extractions with any reagent removed less than 1% of the sesquioxides of the sample, whereby the most dispersed particles were dissolved. We were able to extract about 6% of iron hydroxide from the sample, or about 30% of its total content, with Tamm's reagent and 6%-8% of the total aluminum hydroxide. According to thermal data, amorphous sesquioxides were present in the red earth along with the crystalline forms (Table 4).

As little sesquioxides were removed from laterite, which contains a large amount of goethite and gibbsite, as from clay minerals. Thermographic verification fully confirmed this. The thermograms of laterite prior to and after treatment were very similar: the endothermal effects near 300°C, caused by goethite and gibbsite, remained (Fig. 1).

If sesquioxide does not readily enter solution from clay minerals, they are even more difficult to remove from primary minerals (feldspar, for instance), since these minerals have a strong crystal lattice and usually a small dispersion.

In order to verify Mehra and Jackson's method, we took materials, part of which we knew contained primarily crystalline (bauxite, laterite, nontronite) and amorphous (concretions from sod-podzolic soil and solods) sesquioxides. The thermograms of laterite and bauxite showed endothermal effects at about 300°C, which served as an index of the presence of crystalline sesquioxide minerals. These materials also contained a certain amount of non-silicate amorphous iron and aluminum hydroxides. The thermograms of concretions from sod-podzolic soils and solods showed no effects at 300°C, consequently, the sesquioxides were in the amorphous state. After a three-fold treatment of the materials with the reagents, indicated by Mahra and Jackson, the extracts were analyzed, while the residue was again subjected to thermal analysis. As we can see from Table 5, the Jackson method removes a considerable amount of sesquioxides from bauxite and laterite, but primarily amorphous sesquioxides. The endothermal effect at about 300°C was retained in the thermograms of the samples after extraction (Fig. 2). This proves that crystalline sesquioxides (goethite and gibbsite) partially dissolved.

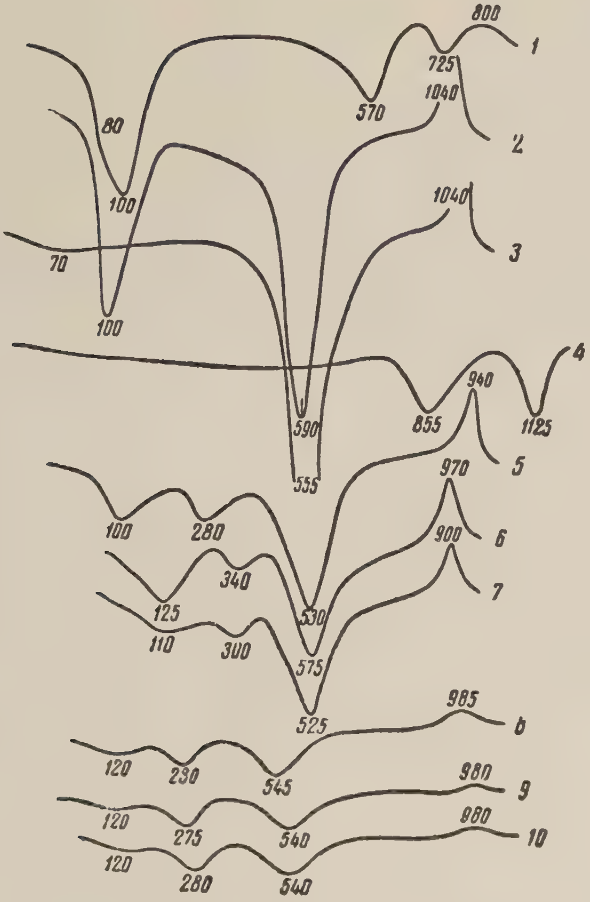

Fig. 1. - Thermograms of minerals and soils. 1 - montmorillonite (askanite); 2 - halloysite, Czechoslovakia; 3 - kaolinite, Pologi, particles 0.001 mm in diameter; 4 - muscovite; Karelia; 5 - red earth, Profile 154, depth 0-20 cm, Chakva; 6 - same, depth 35-45 cm, Chakva; 7 - same, depth 150-200 cm, Chakva; 8 - laterite as a whole, Profile 273, depth 50-60 cm, Vietnam; 9 - laterite, Profile 273, depth 50-60 cm, after a threefold treatment with 0.2 N hydrochloric acid according to the method of Kirsanov; 10 - same, after a threefold treatment with Tamm's reagent.

Table 2

Solubility of iron and aluminum hydroxides of various degrees of crystallinity in various reagents. % of water-free sample

Reagent	Tamm's reagent						0.2 n HCl						Trilon B						Sodium hydrosulfite		
Successive number of extract	1		2		3		1		2		3		1		2		3		1	2	3
Entered solution	Al_2O_3	Fe_2O_3	Al_2O_3	Fe_2O_3	Al_2O_3	Fe_2O_3	Al_2O_3	Fe_2O_3	Al_2O_3	Fe_2O_3	Al_2O_3	Fe_2O_3	Al_2O_3	Fe_2O_3	Al_2O_3	Fe_2O_3	Al_2O_3	Fe_2O_3	Fe_2O_3	Fe_2O_3	Fe_2O_3
Crystalline iron hydroxide	—	7,34	—	5,4	—	1,97	—	1,5	—	3,0	—	1,5	—	5,1	—	3,8	—	3,7	8,8	14,7	9,8
Non-crystalline iron hydroxide	—	45,9	—	24.7	—	9,6	—	2,2	—	19,9	--	25,6	—	6,0	—	6,3	—	6,0	32,2	39,5	16,8
Crystalline aluminum hydroxide	0,34	—	0,79	—	Not det'd.	—	0,98	—	0,23	—	0,21	—	0,66	—	0,23	—	0,13	—	—	—	—
Non-crystalline aluminum hydroxide	68,6	—	30,3	—	1,12	—	7,3	—	15,3	—	9,0	—	1,37	—	1,7	—	1,3	—	—	—	--

Table 3

Solubility of minerals in various reagents, % of initial sample

Reagent	Tamm's reagent									0.2 n HCl						Sodium hydrosulf.	
Sodium hydrosulfite	1			2			3			1		2		3		1	2
Entered solution	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3	Al_2O_3	Fe_2O_3	Al_2O_3	Fe_2O_3	Fe_2O_3	Fe_2O_3
Montmorillonite (askanite)	0,21	0,14	0,33	0,18	0,15	0,32	0,14	0,08	0,05	0,38	0,005	0,18	0,19	0,15	0,005	0,01	0,014
Halloysite	0,27	0,15	0,33	1,73	0,07	0,64	0,39	0,05	0,38	0,15	0.008	0,054	0,012	0,04	0,005	0,026	0,013
Kaolinite	0,16	0,12	0,34	0,05	0,04	0,28	0,09	0,04	0,20	0,03	0,01	0,016	0,009	0,017	0,005	0,025	0,010
Muscovite	0,27	0,15	0.34	0,06	0,09	0,27	0,14	0,01	0,24	0.18	0,02	0,035	0,02	0,016	0,022	0,029	0,016
Red earth (5-15)	0,62	0,55	0,25	0,93	0,94	0,25	1,24	4,82	0,79	0,94	0,05	0,33	0,05	0,23	0,056	Not det'd.	—
Same (3-40)	0,95	0,33	0,21	0,49	1,01	0,16	1,20	5,00	0.61	0,72	0,035	0,28	0,03	0,11	0,044	"	—
" (150-160)	0,75	0,34	0,18	0,33	0,87	0.17	0,89	5,09	0.70	0,69	0,036	0,25	0,03	0,21	0.062	"	—
Laterite (50-60)	0,27	0,12	0,16	0,20	0.12	0.14	0,13	0,19	0,17	0,18	0,04	0,034	0,028	0.034	0,03	—	--
Strongly podzolic soil, Profile 6 (74-87)	0,25	0,38	—	0,12	0,13	—	0,14	0,07	—	0,33	0,08	0,19	0,07	0,14	0.06	—	—

Note: Comma represents decimal point.

Table 4

Amount of sesquioxides and silica in three successive extracts by Tamm's method

Material studied, depth, cm	Total content, %			Found in the three extracts					
				% of sample			% of total content		
	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3
Montmorillonite	64,7	20,8	5,0	0,70	0,53	0,37	1,08	2,5	7,4
Halloysite	53,4	40,9	1,90	1,35	2,39	0,27	2,5	5,8	14,2
Kaolinite	51,2	46,4	1,6	0,82	0,30	0,20	1,6	0,6	12,5
Muscovite	52,5	29,5	3,77	0,85	0,47	0,25	1,6	1,6	6,7
Red earth (5-15)	41,7	33,2	19,3	1,29	2,79	6,31	3,1	8,4	32,7
Same (30-40)	36,6	33,7	23,8	0,98	2,64	6,34	2,9	7,9	26,6
" (150-160)	39,3	34,2	22,9	1,55	1,97	6,30	3,9	5,7	27,5
Laterite (50-60)	35,5	32,0	28,0	0,47	0,60	0,43	1,3	1,9	1,5
Sod-podzolic soil (74-87)	78,6	12,2	2,64	Not det'd.	0,51	0,58	—	4,2	21,9

Note: Comma represents decimal point.

Table 5

Amount of sesquioxides and silica in three successive extracts by Jackson's method, % of ignited sample

Material studied, depth, cm	Total content, %			Found in the three extracts					
				% of sample			% of total content		
	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3	SiO_2	Al_2O_3	Fe_2O_3
Laterite, Vietnam, Profile 273(50-60)	35,5	32,0	28,0	1,10	None	20,20	3,01	None	71,7
Concretions from laterite, Vietnam, Prof. 273 (30-40)	29,0	16,36	52,8	1,40	0,50	14,46	4,80	3,05	27,3
Concretions fr. solod Askaniya-Nova, Prof. 1960 (4-20)	54,6	18,4	16,1	1,83	0,59	15,10	3,4	3,20	95,6
Concretions from sod-podzolic soil, Podushkino, Moscow Oblast', Profile 3 (18-28)	64,9	16,3	13,3	3,80	0,88	13,30	5,50	4,90	100
Bauxite, Profile 56,	10,4	53,8	33,9	1,10	3,30	19,90	10,0	6,13	59,4
Nontronite, Urals	58,3	7,3	26,9	Not det'd.	Not det'd.	3,71	Not det'd.	Not det'd.	13,8

Note: Comma represents decimal point.

The experiment with the removal of iron from bauxite and nontronite is of special importance. In nontronite iron is primarily a component of tetrahedrons and is partially in a non-silicate form, i. e., in the form of an admixture. The thermograms of nontronite, prior to and after its treatment with the Mehra-Jackson reagent, are very similar, i. e, the lattice of the mineral was not destroyed by this reagent. The only difference in the thermograms was that after the treatment of nontronite the effect at 375°C decreased as a result of the removal of non-silicate iron. There was no difference either in the thermograms of bauxite, which indicates that its structure was retained after treatment with the same reagent.

Relatively more sesquioxides were extracted from concretions in solod and podzolic soil than from laterite. For instance, 95.6% of the total content of iron was extracted from concretions

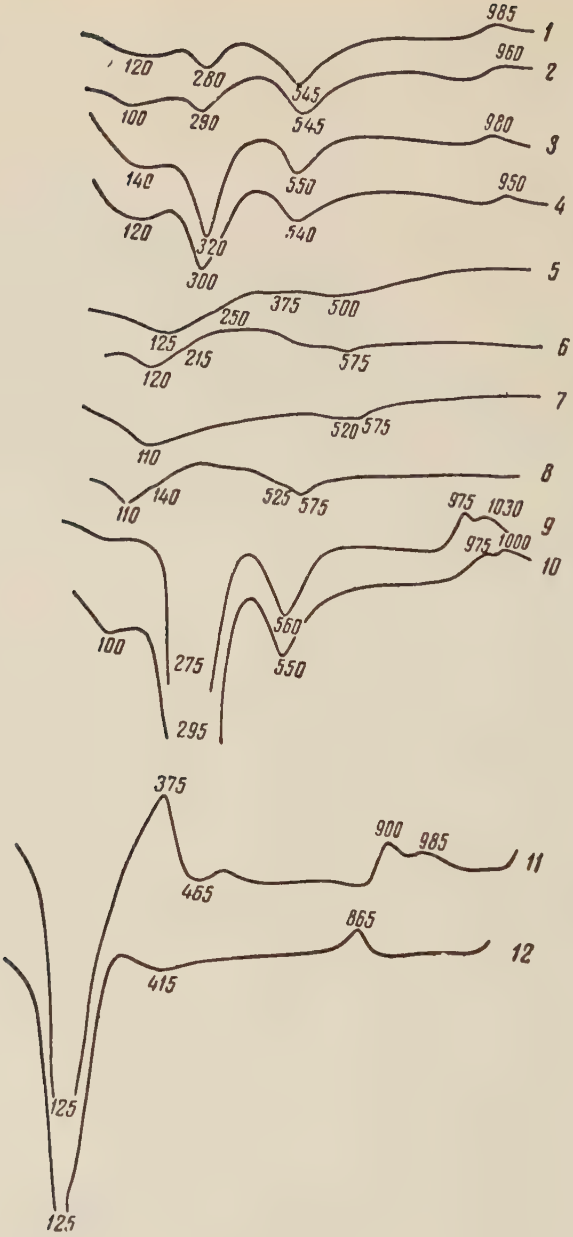

Fig. 2. - Thermograms of the samples prior to and after a threefold treatment by Jackson's method. 1 - laterite on granite, Profile 273, depth 50-60 cm; 2 - same after treatment; 3 - concretions from laterite, Profile 273, depth 30-40 cm; 4 - same after a threefold treatment with the reagent; 5 - concretions from solod, Profile 1960, depth 4-10 cm, Askaniya Nova; 6 - same after a threefold treatment with the reagent; 7 - concretions from strongly podzolic soil, Profile 3, depth 18-28 cm, Podushkino, Moscow Oblast'; 8 - same after a threefold treatment with the reagent; 9 - bauxite, Profile 56; 10 - same after a threefold treatment with the reagent; 11 - notronite, Urals; 12 - same after a threefold treatment with the reagent.

in solod, and almost 100% from concretions in sod-podzolic soil, whereas 71.7% was removed from laterite and only 27.3% from laterite concretions.

Aluminum was extracted in much lesser amounts, since a considerable part of it was bound in the form of alumino-silicates — clay and non-clay minerals. As we can see from the thermograms, laterite contained kaolinite, and sod-podzolic soil and solods contained hydromica and minerals of the montmorillonite group.

After the present article was sent to the printer, the article of I. G. Tsyurupa (5) appeared, which was written on our suggestion (4, p. 113). The author concluded that the Tamm, Deb, and Stefanovits reagents remove a considerable amount of silicate iron. This conclusion and the ensuing implications are erroneous, since the assumption was made that the materials were completely crystalline. Our thermal and X-ray investigations showed that they also contain the amorphous phase. As a result of the lack of a reliable mineralogical verification in the same work, the method of Deb has been wrongly evaluated. It is presumed to extract the same amount of crystalline and amorphous iron oxide.

Conclusions

1. Sesquioxides are contained in the soil in the silicate (mineral components) and non-silicate (in a free state) forms. Non-silicate sesquioxides may be crystalline, as for instance goethite ($Fe_2O_3 \times H_2O$) and gibbsite ($Al_2O_3 \times 3H_2O$), and amorphous. The solubility of the foregoing forms of sesquioxides varies greatly.

2. In order to dissolve non-silicate sesquioxides five reagents were tested: Tamm's reagent, 0.2 N hydrochloric acid (Kirsanov method), trilon B (Stefanovits method), sodium hydrosulfite (Deb method), and the same reagent in a mixture with sodium citrate and sodium bicarbonate (Mehra and Jackson method). None of the foregoing reagents dissolves sesquioxides in one treatment. Crystalline sesquioxides are especially hard to dissolve. Three successive extractions increase solubility 2-3 times. The best solvents for iron hydroxide is sodium hydrosulfite — Tamm's reagent for dissolving total sesquioxides, and then come hydrochloric acid and trilon B.

3. Amorphous non-silicate sesquioxides dissolve readily in Tamm's reagent after three successive extractions (70%-99.9% of total content), less in hydrochloric acid (31%-47%), and even less in trilon B (not more than 12.6%). Sodium hydrosulfite dissolves 88% of amorphous iron hydroxide. Mahra and Jackson's method dissolves primarily amorphous sesquioxides and partially crystalline sesquioxides.

4. As free sesquioxides dissolve, an insignificant amount of the most highly dispersed portion of amorphized clay minerals also dissolves and is converted to an R_2O_3 and SiO_2 solution, however, their amount after 3 extractions rarely exceeds 1% of the sample. Tamm's reagent affects the minerals more strongly than hydrochloric acid and sodium hydrosulfite. The solubility of minerals depends on their nature, dispersion, and other factors.

5. Three successive extractions with Tamm's or Mehra and Jackson's reagents may be recommended for dissolving amorphous sesquioxides; the Deb method is recommended for dissolving iron hydroxide alone. Hydrochloric acid and trilon B are less suitable. Crystalline sesquioxides dissolve partially at the same time that amorphous sesquioxides dissolve.

6. In red earths and laterites free sesquioxides are primarily, but not completely, in the crystalline form, therefore it is impossible to dissolve them with the reagents tested. In podzolic soils non-silicate sesquioxides are primarily represented in the amorphous form and therefore they can be dissolved to a considerable degree, but not completely, by a threefold treatment with the Tamm and Mehra and Jackson reagents.

7. The opinion of Mehra and Jackson that their reagent dissolves crystalline sesquioxides has not been confirmed by our experiments.

8. To determine non-silicate sesquioxides it is expedient to use a threefold extraction of Tamm or Mehra and Jackson in conjunction with thermal and X-ray verification of the material.

Received October 18, 1960

BIBLIOGRAPHY

1. GORBUNOV, N. I. 1954. Mineralogical composition of red earths. Papers presented at the V International Congress of Soil Science, Izd. Akad. Nauk SSSR.
2. GROBUNOV, N. I. 1959. Importance of minerals for soil fertility. Pochvovedeniye, No. 7.
3. KIRSANOV, A. T. 1958. Methods for the agricultural-chemical analysis of soils. Izd. Akad. Nauk SSSR.
4. TSYURUPA, I. G. 1958. Influence of the degree of crystallinity of iron compounds on their solubility. Tr. Pochv. in-ta im. V. V. Dokuchayeva. Vol. 53:113.
5. TSYURUPA, I. G. 1961. Problem of the removal of free (non-silicate) iron and aluminum from soils and clay. Pochvovedeniye. No. 4.
6. DEB, B. C. 1950. The estimation of free iron oxides in soils and clays and their removal, J. Soil Sci. v. 1 N 2.
7. MEHRA, O. P., M. L. JACKSON. 1960. Clays and clay minerals, N. Y. Lnd. [1] Vol. 5. ([1]Missprint in Russian text.)
8. TAMM, O. 1934. Über die Oxolatmethode in der chemischen Bodenanalyse, Medd. skogs förs inst. Stockholm H. 27.
9. STEFANOVITS, POL. 1955. A talajok Szabad aluminum-es vastartalmanak maghatarozasa Komplexonnal. Agrokém. és talaj. t, 4, Nr. 3.

METHOD OF EXTRACTING ADSORBED AMMONIUM FROM SOILS

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We have shown earlier (4, 5) that when extracting adsorbed ammonium by the prolonged treatment of the soil with 1% KCl (8) hydrolysis of amide nitrogen may take place in saline soil suspensions. This is apparently associated with the activity of soil enzymes — amidases. The source of soil enzymes are living microorganisms, as well as dead microbial cells of the plants and animals. The degree of activity of soil enzymes has been used by certain investigators to evaluate comparatively the fertility of various soils (1, 2, 3, 6, 7).

The present article presents the results of investigations made in order to clarify the problem of whether the foregoing hydrolysis of amide nitrogen in saline soil suspensions is associated only with the activity of amidases accumulated in the soil, or whether the life activity of ammonifying micro-organisms continues under these conditions.

The ammonifiers were artificially added into the soil after the amidase enzymes contained in it were destroyed. The method of investigation was the following. Ten-gram samples of air-dried meadow-sierozem soil were moistened with 5 ml of water and sterilized in the Koch apparatus in order to destroy the enzymes. Saline soil suspensions with 1%

Table 1

Hydrolysis of amide nitrogen during the addition of ammonifiers and urea to saline suspensions of sterilized soil in the presence and absence of toluene. Ammonium nitrogen, mg/kg of soil, 1959

Treatment No.	Soil	Experimental treatment	Ammonium nitrogen found	Calculated ammonium nitrogen	
				Calculation factors [a]	Ammonium nitrogen
1	Without soil	KCl + urea	0	—	—
2		KCl + ammonifiers	8	—	—
3		KCl + ammonifiers + toluene	7	—	—
4	Sterilized	Soil + KCl	8	—	—
5		Soil + KCl + toluene	8	—	—
6		Soil + KCl + urea	11	6—4	+3
7		Soil + KCl + urea – toluene	12	7—5	+4
8		Soil + KCl + ammonifiers	19	8—2—4,	+3
9		Soil + KCl + ammonifiers + toluene	17	9—3—5	+2
10		Soil + KCl + ammonifiers + urea	72	10—2—6	+53
11		Soil + KCl + ammonifiers + urea + toluene	28	11—3—7	+9
12	Non-sterilized	Soil + KCl	7	—	—
13		Soil + KCl + toluene	8	—	—
14		Soil + KCl + urea	250	14—12	+243
15		Soil + KCl + urea – toluene	298	15—13	+290

[a] The numbers in this column, giving the treatment Nos., represent the amount of ammonium nitrate found in the soil in the given treatments. For instance, 11-3-7 indicates that: the content of ammonium nitrogen in the soil, obtained in treatment 11, minus its content in treatment 3, minus its content in treatment 7 amounts to 28-7-12 = + 9 mg/kg of soil.

Table 2

Hydrolysis of amide nitrogen during the composting of sterilized soil with urea and ammonifiers in the presence and absence of toluene. Ammonium nitrogen, mg/kg of soil

Treatment No.	Soil	Experimental treatment	Ammonium nitrogen found	Calculated ammonium nitrogen	
				Calculation factors[a]	Ammonium nitrogen
1	Without soil	KCl + urea	0		
2		KCl + AMM_1	8		
3		KCl + AMM_1 + toluene	7		
4		KCl + AMM_2	6		
5		KCl + AMM_2 + toluene	6		
6	Meadow-sierozem	Soil	13		
7		Soil + toluene	13		
8		Soil + urea	14		
9		Soil + urea + toluene	14		
10		Soil + AMM_1	27	10—6—2	+6
11		Soil + AMM_1 + toluene	20	11—7—3	0
12		Soil + AMM_1 + urea	798	12—8—2	+776
13		Soil + toluene	32	13—9—3	+11
14		Soil + AMM_2 + urea	141	14—8—4	+121
15		Soil + toluene	29	15—9—5	+9
16	Sierozem-meadow-soil	Soil	14		
17		Soil + toluene	16		
18		Soil + urea	16		
19		Soil + urea + toluene	16		
20		Soil + AMM_1	26	20—16—2	+4
21		Soil + AMM_1 + toluene	19	21—17—3	—4
22		Soil + AMM_1 + urea	397	22—18—2	+374
23		Soil + toluene	30	23—19—3	+1
24		Soil + AMM_2 + urea	189	24—18—4	+7
		Soil + toluene	29	25—19—	+167

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[a] See note in Table 1.

KCl (soil:solution ratio of 1:10, i. e., 100 ml of 1% KCl to 10 g of air-dry soil) were made of the sterilized samples. Urea (15 mg) and ammonifiers, extracted from the same soil, were added to the suspension, depending on the treatment used. The soil was left to interact with the various components of the saline suspensions for 48 hours in the presence and absence of toluene. The experimental scheme and the results are shown in Table 1.

The indices of treatments No. 2 and 3 characterize the presence of ammonium nitrogen (in milligrams per kilogram of soil) in the amount of the ammonifier suspension (0.5 ml) added to each sample of saline suspension. The same table shows data from investigations made on the same, but non-sterilized soil (treatments Nos. 12-15).

As we can see from Table 1, the addition of ammonifiers to the saline suspension of sterilized soil in the absence of toluene also produced the hydrolysis of urea (treatment 10), even though it was much weaker than in the non-sterilized soil (53 mg against 243 mg). The addition of toluene greatly depressed the process of the ammonification of urea induced by ammonifying micro-organisms (treatment 11 as compared with treatment 10), whereas hydrolysis of urea was noticeably intensified in the presence of toluene (290 agains 243 mg/kg) in the saline suspensions of non-sterilized soil, where the amidase enzymes were not destroyed. Consequently, the hydrolysis of amide nitrogen in saline soil suspensions with 1% KCl during the extraction of adsorbed ammonia from the soil in the presence of toluene (4, 5) is only associated with the activity of amidases, accumulated earlier in the soil, since under these conditions the ammonifying activity of ammonifiers is sharply depressed.

In the other treatments, urea and the ammonifiers were added to the soil and not to the saline suspension. The method of investigation consisted of the following. Ten-gram samples of sterilized and air-dry soil were mixed with 20 mg of urea and placed in flat-bottomed flasks of about 100 ml capacity. To this was added 0.5 ml of the ammonifier suspension. After the soil was thoroughly mixed and moistened to 85% of total moisture capacity, about 20-25 drops of toluene were added to it. Then the flasks were sealed with cotton stoppers and placed for 48 hours in a thermostat at 20°-25°C. The second day, after the beginning of composting, 10 drops of toluene were again added to each flask. At the end of the composting period the amount of ammonium nitrogen in the soil was determined as usual with 1% KCl at a soil solution ratio of 1:10 after a 20-hour infusion of the soil suspensions (8).

The investigations were conducted on meadow-sierozem and sierozem-meadow soils and two strains of ammonifiers.[1] The first was isolated from the same meadow-sierozem soil, and the second, from the light sierozem soil of the Chuya valley. In Table 2 the first strain is designated with AMM_1 and the second, with AMM_2. The results of the investigations, presented in Table 2, confirm the data in Table 1. The addition of ammonifiers to non-sterilized soil caused a pronounced hydrolysis of urea, while it was almost completely supressed after the addition of toluene.

Conclusions

The experiments made showed that the extraction of adsorbed ammonium by prolonged treatment of the soil with 1% KCl in the presence of toluene in saline suspensions can be accompanied by the hydrolysis of amide nitrogen and the formation of ammonia as a result of the biological activity of amidase enzymes accumulated earlier in the soil. In the absence of toluene this process may result from the ammonifying activity of living ammonifying micro-organisms.

Received September 22, 1960

BIBLIOGRAPHY

1. VIGOROV, L. I. 1958. Characteristics of the catalase of podzolic soils. Dokl. Akad. Nauk SSSR. 122 (6).
2. VLASYUK, P. A., K. M. DOBROTVORSKAYA, S. A. GORDIYENKO. 1956. Urease activity in the rhizosphere of agricultural crops. Dokl. VASKHNIL. No. 8.
3. GOFMAN, YE. 1956. Enzymes in the soil and their importance for its biology and fertility. Biologya. No. 13.
4. DASHEVSKIY, L. I. 1959. Method of determining adsorbed ammonium in the soil. Pochvovedeniye. No. 2.
5. DASHEVSKIY, L. I. 1960. Specification of the method of determining ammonia in the soil. Pochvovedeniye. No. 8.
6. KUPREVICH, F. V. 1951. Biological activity of the soil and methods of determining it. Dokl. Akad. Nauk SSSR. Vol. 79.
7. MASHTAKOV, S. M., T. I. KULAKOVSKAYA, and S. M. GOL'DINA. 1954. Enzyme activity and respiration intensity as indices of the biological activity of the soil. Dokl. Akad. Nauk SSSR. 98 (1).
8. Agrochemical and agrophysical methods of investigation in irrigated cotton-growing areas. SOYUZNIKHI, Tashkent. 1941.

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[1] Microbiologists E. G. Vukher, from the Soil Science Department of the Academy of Sciences of the Kirgiz SSR, and V. A. Timofeyev, from the Kirgiz Scientific-Research Institute of Agriculture, participated in the isolation of the ammonifiers.

REVIEWS

AGRICULTURAL CHEMISTRY

JANOS DI GLERIA, Published by the Academy of Sciences. Budapest, 1959

Fifty years ago the teacher of Professor Di Gleria, the well-known soil scientist Zigmoid published a manual on agricultural chemistry. The new book of the outstanding chemist-soil scientist Janos Di Gleria discusses the same problems from the modern scientific point of view.

The book consists of the following eight parts.

The first part describes in a systematic way the history of the development of agricultural chemistry, beginning with Palissy (1563) to our days. An important place is devoted to Russian and Soviet investigators (Timiryazev, Pryanishnikov, Gedroyts, Kostychev, and others).

The second part (pp. 33-11) contains information on the elementary chemical composition of plants and on the most important organic compounds in plants (carbohydrates, lignium, organic acids, lipoids, terpenes, carotinoids, sterols, angocyanogens, nitrogen compounds, vitamins, enzymes, hormones, and antibiotics).

The third part (pp. 115-173) discusses factors in the development and productivity of plants. These factors include also climatic conditions, such as light, air temperature, and water. The properties of the soil as the medium for plant development are discussed in great detail. Here we find data on the composition of inorganic compounds in the soil, its organic substances, soil solution, soil air, fauna and flora, and, in particular, the microflora of soils. The most important soil properties, which directly determine the productivity of plants, are examined, namely: the moisture properties, and the content and availability of nutrients in the soil. Adsorption and protolytic processes taking place on colloidal soil particles are characterized, as well as oxidation-reduction phenomena (the capture and release of electrons). Professor Di Gleria introduces his new research data in this field of the physical chemistry of soils.

The fourth part of the book (pp. 177-249) is devoted to the problem of plant nutrition and the formation of organic compounds in them. It contains information on biochemical reactions, the activity of enzymes and their variety, and on photosynthesis (synthesis of carbohydrates, proteins, and lipoids). Mineral elements used for plant nutrition (macroelements, micro-elements, and ultramicro-elements) are also examined. Here the author touches on problems of the possible mathematical analysis of data on plant yield, depending on the main factors (especially on the nutrient contents), and, in particular, of the possible use of the Mitscherlich equation, etc.

The fifth part of the book (pp. 254-284) discusses organic fertilizers (manure, its storage, peat, plant residue, hay, industrial waters, green manure, etc.). This part contains numerous analytical data on organic fertilizers.

The sixth part (pp. 287-319) contains materials on mineral fertilizers, and discusses problems of the manufacture of mineral fertilizers and their effect of plant yield. The problems of soil liming and application of gypsum, and the use of microelement fertilizers are examined separately.

The seventh part of the book (pp. 323-343) discusses problems of the use of fertilizers and fertilization systems, primarily on the basis of the literature (mostly Soviet literature).

The eighth part (pp. 347-369) is devoted to methods of determining the deficiency of nutrients in soils and the effectiveness of fertilizers. The principles of chemical methods of determining plant nutrients in soils (the methods of Lemmerman-Frezenius Zigmond, Egner, the isotope method, and electrodialysis) are described briefly. Physiological methods (that of Mitscherlich, Neubauer, the use of the Azotobacter, Aspergillus, etc.) are also considered. The field methods described include various methods of arranging experimental plots (Latin, random blocks), as well as methods for the statistical analysis of experimental data.

The book has a large list of references (325) having names and subject matter, as well as series of colored pictures of plants which are deficient in certain elements in plants.

The book is well organized. All the problems of agricultural chemistry are presented concisely and are illustrated with the most important data. The book can serve as a manual for specialists in their scientific and practical work. It would be desirable to have it translated into Russian.

Professor Di Gleria's book contains a very flattering, short review which appeared in the "Bulletin of the International Society of Soil Science" (No. 16:10, 1960).

Reviewed by I. N. Antipov-Karatayev

BIBLIOGRAPHY

FACTORS OF SOIL FORMATION, GENESIS, GEOGRAPHY, AND THE CARTOGRAPHY OF SOILS

1. Agricultural-climatic handbooks: Eastern Kazakhstan Oblast'. 1960. Leningrad, Gidrometeoizdat. 125 pp. with ill., 1 map sheet. Kirovo Oblast'. 1960. Leningrad, Gidrometeoizdat. 191 pp. with ill., maps. Estonian SSR. 1960. Leningrad, Gidrometeoizdat. 198 pp. with maps. Arkhangel'sk Oblast'. 1961. Leningrad, Gidrometeoizdat. 200 pp. with ill. Bibliog. 36 refs. Astrakhan' Oblast'. 1961. Leningrad, Gidrometeoizdat. 143 pp. with ill. Bibliog. p. 119. Dzhambul' Oblast'. 1961. Leningrad, Gidrometeoizdat. 143 pp. with ill. Bibliog. 29 refs. Kaliningrad Oblast'. 1961. Leningrad, Gidrometeoizdat. 129 pp. with ill. Bibliog. p. 124. Kostroma Oblast', 1961. Leningrad, Gidrometeoizdat. 168 pp. with ill. Bibliog. p. 140. Rostov Oblast'. 1961. 206 pp. with ill. Bibliog. 28 refs.

2. AYNEMER, A. I. 1961. Fossil takyr-like formations. Tr. Vses. n.-i. geol. in-ta. Vol. 46:364-372. Bibliog. 8 refs.

3. BEZSONOV, A. I. 1960. Collected works. (In honor of the 85th birthday and 60 years of scientific activity. Chief editor, U. U. Uspanov). (In-t pochvovedeniya Akad. Nauk KazSSR). Alma-Ata, Izd. Akad. Nauk KazSSR. 256 pp. portrait. Bibliog.: list of the major works of A. I. Bezsonov.

4. BESEDNOV, N. A. 1960. Desalinization of soils and the "freshening" of ground waters below the bottom of horizontal drains. Izv. Akad. Nauk TurkmSSR. Otd. s.-kh. i biol. nauk. No. 2:3-28. Bibliog. p. 28. Summary in the Tadzhik language.

5. BOLYSHEV, N. N. 1961. Role of algae in soil formation. Vestn. Mosk. un-ta. Ser. 6, Biologiya, pochvovedeniye. No. 2:67-75. Bibliog. 12 refs.

6. VASIL'YEVA, I. V. 1961. Limit of the Moscow glaciation and its importance to the landscape. Vestn. Mosk. un-ta. Ser. 5. Geografiya. No. 3:62-66, with maps. Bibliog. 10 refs.

7. VILENSKIY, D. G. 1961. Soil regionalization of the central regions of the non-chernozem belt. Pochv. rayonirovaniya SSSR. No. 2:52-65, with tables.

8. GENUSOV, A. Z., B. V. GORBUNOV, and N. V. KIMBERG. 1960. Soil-climatic regionalization of Uzbekistan for agricultural purposes. Tashkent. 118 pp. Bibliog. pp. 108-110.

9. GORBUNOVA, M. A. 1961. Main soil features in the lower reaches of the Volga River delta. Tr. Astrakhansk. zapovednika. No. 5:49-52, with tables.

10. GRADOBOYEV, N. D., V. M. PRUDNIKOVA, and I. S. SMETANII. 1960. Soils of the Omsk Oblast'. Omsk kn. izd. 374 pp. with graphs. Bibliog. pp. 369-373.

11. GROSSET, G. E. 1961. Fluctuations of the boundary between forest and steppe during the Holocene in the light of studies of the displacement of zones. Byul. Mosk. o-va ispyt. prirody. Vol. 66. Otd. biol. No. 2:65-84. Bibliog. pp. 81-84.

12. DARASELIYA, M. K. 1961. Work on the study and cultivation of red earths and subtropical podzolic soils. Subtropich. kul'tury. No. 1-2:115-134.

13. ZAVALISHIN, A. A. and A. A. KHANTULEV. 1961. Soil regionalization of the northern and northwestern European USSR. Pochv. rayonirovaniye SSSR. No. 2:3-51, with maps.

14. ZOL'NIKOV, V. G. 1961. Soil-landscape regions of Western Yakutiya. Pochv. rayonirovaniye SSSR. No. 2:206-267.

15. KAZINTSEV, A. L. and D. I. KOLPIKOV. 1960. Nature of the interaction between soil and vegetation in hay fields and pastures on black earths. (With an ecological-physiological evaluation of plants of the soil-vegetation elements of complexes). Tr. Stavropol'sk. s.-kh. in-ta. No. 9:33-42. Bibliog. 9 refs.

16. KAMYSHEV, N. S. 1961. Principles of the classification of the steppes in central-chernozem regions. Byul. Mosk. o-va ispyt. prirody. Vol. 66. Otd. Biol. No. 3:51-67. Bibliog. pp. 65-67.

17. KAURICHEV, I. S. and M. V. BEZILINSKAYA. 1961. Genetic characteristics of solonetzes and solods in Western Siberia. Dokl. TSKhA (Mosk. s.-kh. akad.). No. 60-99-101.

18. KIRILLOV, M. and P. BUGAKOV. 1960. Scheme for the soil regionalization of the Krasnoyarsk Kray. Part 2. Forest-steppe, steppe, and mountain-forest zone. Tr. Krasnoyarks. s.-kh. in-ta. Vol. 7:3-1 16. Bibliog. 9 refs.

19. KORZUN, M. A., O. V. MAKEYEV, N. A. NOGINA, and K. A. UFIMTSEVA. 1961. Soil regionalization of Baikal Siberia. Pochv. rayonirovaniye SSSR. No. 2: 146-205.

20. KOROTAYEV, N. YA. 1961. Soil regionalization of the Perm' Oblast'. Pochv. rayonirovaniye SSSR. No. 2:66-145.

21. KREYDA, N. A. 1960. Soil-geographic conditions in the lower reaches of the Pechora River. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Pochv. in-t im. Dokychayeva). Leningrad. 17 pp.

22. KRICHMAR, M. S. 1901. Soil and climatic resources of the Odessa Oblast', their most rational utilization for the further development of viticulture, and the quality of its production. Author's dissertation for a candidate's degree in agricultural sciences (Kishinevsk. s.-kh. in-t). Odessa. 76 pp.

23. KRYLKOV, YU. V. 1960. Litological-facies analysis of Quaternary deposits in the area of the projected Yavan system of irrigation. Izv. Akad. Nauk TadzhSSR. Otd. geol.-khim. i tekhn. nauk. No. 1:69-81. Bibliog. pp. 154-163. Summary in the Tadzhik language.

24. LICHKOV, B. L. 1960. Natural waters of the Earth and the litosphere. (Akad. Nauk SSSR. Zap. Geogr. o-va SSSR. Vol. 19). Moscow-Leningrad, Izd. Akad. Nauk SSSR. 164 pp. with ill. Bibliog. pp. 154-163.

25. MAMYTOV, A. M. and G. I. ROYGEN. 1961. Soil regionalization of Kirgiziya. Frunze, Izd. Akad. Nauk KirgSSR. 155 pp. Bibliog. pp. 143-153. Summary in the Kirgiz language.

26. NADEZHKIN, B. V. 1961. The Lena-Angara forest-steppe (soil-geographical outline). (Akad. Nauk SSSR. Sib. otd., Bost.-Sib. fil.). Moscow, Izd. Akad. Nauk SSSR. 328 pp. with ill. Bibliog. pp. 313-327.

27. ORLOVSKIY, N. and N. KAZANTSEY. 1960. Systematic list of soils in Krasnoyarsk Province. Tr. Krasnoyarsk. s.-kh. in-ta. Vol. 7:17-48.

28. PERSHINA, M. N. 1961. Light-chestnut soils of the Yergeney. Dokl. TSKhA (Mosk. s.-kh. akad.). No. 60:117-122.

29. PERSHINA, M. N. and O. G. PEN'KOV. Main features of foil-formation conditions in the dry steppe and subtropical zone of the Karabakh steppe in the Kura-Araks lowland. Ibid., pp. 137-141. Bibliog. 11 refs.

30. POPAZOV, D. I. 1961. Soil formation process and the productivity of soils (taking certain natural regions of the USSR as an example). Author's summary of his dissertation for a doctor's degree in agricultural sciences. (N.-i. in-t zemledeliya Akad. s.-kh. nauk BSSR). Moscow. 56 pp.

31. Soil regionalization of Baikal Siberia. 1960. (Akad. Nauk SSSR, Sib. etd. Buryat. kompleksnyy n.-i. in-t). Uland-Ude. 68 pp. with 1 map sheet. Bibliog. pp. 66-67.

32. Soil regionalization of the USSR. 1960. Collection edited by D. G. Vilenskiy. No. 1. Moscow, Izd. Mosk. un-ta. 240 pp. with ill. and maps.

33. Soils of the Southern Urals and of the Volga Region. 1960. (Collection of articles under the editorship of S. N. Taychinov). No. 4. (Bashkir. fil. Akad. Nauk SSSR, In-t biol., Bashkir. otd. Vses. o-va pochvovedenov). Ufa. 235 pp. with ill.

34. RIKHTER, G. D. 1961. Natural regionalization of the USSR. Izv. Akad. Nauk SSSR. Ser. geogr. No. 3:3-13, with maps.

35. ROZANOV, B. G. 1961. Brown forest soils in Western Belorussia. Vestn. Mosk. un-ta. Ser. 6, Biologiya, pochvovedeniye. No. 2:55-66. Bibliog. 14 refs.

36. RUBILIN, YE. V. 1960. Natural zones of the North Ossetian ASSR and description of the major soil groups by zones. Izv. Sev.-Oset. NII. 22(3):5-26, with tables.

37. TALAKHADZE, G. R. 1961. Genetic relationship between solonetzic and compact soil of Eastern Georgia. Tr. n.-i. in-ta zemledeliya (Akad. s.-kh. nauk GruzSSR). Vol. 12:319-330. Bibliog. 13 refs.

38. Physiographic Regions of the Lower Volga Region. 1961. (P. S. Kuznetsov, editor). Saratov, Izd. Saratovsk. un-ta. 144 pp. with ill. Bibliog. 43 refs.

39. SHEVCHENKO, A. I. 1961. Hydrogeological classification of irrigation regions in Uzbekistan. (Akad. Nauk UzSSR. in-ta gidrogeologii i inzh. geologii). Tashkent, Izd. Akad. Nauk UzSSR. 155 pp. Bibliog. 249 refs.

40. Ecological-geographical and meliorative soil Investigations in Kazakhstan. 1961. (Collection of articles. Chief editor, U. U. Uspanov). Tr. In-ta pochvovedeniya Akad. Nauk KazSSR. Vol. 12. Alma-Ata, Izd. Akad. Nauk KazSSR. 205 pp. with ill.

41. DURAND, J. H. 1960. Les sols d'Israel et

l'agriculture irriguée. Bull. Trav. Sect. Pedologie et Agrologie, No. 6, 23 pp.

42. Escambia County, Florida. 1960. (Survey by James H. Walker and Victor W. Carlisle. Report by Victor W. Carlisle. Correlation by Allen H. Hasty). Wash., 87 p. (Soil survey. Ser. 1955, No. 8).

43. La Crosse County, Wisconsin. 1956. (Report by Marvin T. Beatty and others). Wash., 1960. 93, p. (Soil survey. Ser. No. 7).

44. Lancaster County, Pennsylvania. 1959. (Report by John B. Carey. Soils surveyed by R. K. Craver and others). Wash., 132 p. (Soil survey. Ser. 1956, No. 4).

45. Rockingham County, New Hampshire. 1959. (Frieldwork by Arthur E. Shearin and others). Wash. 78 p. (Soil survey Ser. 1954, No. 5).

46. Soil classification. 1960. A comprehensive system. 7th approximation. 265 p. (U. S. Dept. Agric. Soil survey staff. Soil conservation service).

SOIL MINERALOGY

47. D'YAKONOV, YU. S. 1961. Quantitative X-ray analysis of mixtures of clay minerals. Materialy Vses. n.-i. geol. in-ta. No. 45:207-237. Bibliog. p. 231.

48. Investigation of the Process of Cation and Water Sorption in Bentonitic Clays. Part 4. Eyrish, M. V. Sorption properties and microstructure of montmorillonite. Izv. vyssh. ucheb. zavedeniy. Khimiya i khim. tekhnol. 4 (1): 64-69. Bibliog. 16 refs.

49. KOVALEV, G. A. and YU. S. D'YAKONOV. Classification of clay minerals and crystalline silicates similar instructure. Ibid. pp. 175-184, with tables. Bibliog. pp. 183-184.

50. OVCHARENKO, F. D. 1961. Hydrophylic properties of clays and clay minerals. (In-t obshchey i neorganich. khimii Akad. Nauk UkSSR). Kiev, Izd. Akad. Nauk UkSSR. 291 pp. with ill.

51. SHUMENKO, S. I. 1961. Clay minerals of marl-cretaceous rocks in the Northern Donetz valley. Dokl. Akad. Nauk SSSR. 138 (1):199-202, with tables. Bibliog. 8 refs.

52. ANDREW, R. W. and others. 1960. Intersalation as a technique for differentiation of kaolinite from chloritic minerals by X-ray diffraction. Soil Sci. Soc. America Proc. 24, No. 5, p. 422-24.

53. An investigation of the intercept method for determining the proportion of dolomite and calcite in mixtures of two. 1. Turner, R. C. Theoretical aspects of the rate of solution of dolomite when a number of crystals are present. 2. Turner, R. C. Skünner, S. I. M. Experimental rates of solution of dolomite and calcite in samples consisting of a number of crystals. 1960. Canad. J. Soil Sci. 40, No. 2, p. 219-41.

54. AOMINE, S., Y. SHIGA. 1960. Clay minerals of some sendos in Fukuoka. Soil and Plant Food 6, No. 1, p. 19-24.

55. CALVERT, D. V. and others. 1960. The effect of exchangeable calcium on the retention of phosphorus by clay fractions of soils of the Memphis catena. Soil Sci. Soc. America Proc. 24, No. 5, p. 333-336.

56. COLEMAN, N. T. and others. 1960. An unexpected reaction between Al-clay or Al-soil and $CaCl_2$ — Soil Sci. Soc. America Proc. 24, No. 5, p. 419-20.

57. DAKSHINAMURTI, C. 1960. Studies on the conductivity of clay systems. Soil Sci. 90, No. 5, pp. 302-305.

58. KHAN, D. H. 1960. Clay mineral distribution in some rendzinas, red-brown soils, and terra rossas on limestones of different geological ages. Soil Sci. 90 No. 5, p. 312-19, Bibliog. p. 318-19.

59. TABIKH, A. A. and oth. 1960. Cation exchange hysteresis in clay minerals. Soil Sci. 90, No. 4, p. 219-26. Bibliog. p. 225-26.

PHYSICAL PROPERTIES OF SOILS AND METHODS OF INVESTIGATION

60. BOL'SHKOY, A. F. 1961. Water regime of thick chernozems of the Central Russian Plain. (Akad. Nauk SSSR. Pochvennyy in-t im. V. V. Dokuchayeva). Izd. Akad. Nauk SSSR. Moscow. 200 pp. with ill. Bibliog. 71 refs.

61. GURKINA, N. F. 1961. Ground water regime in the northwestern part of the Volga-Ural interfluve in the Caspian lowland. Author's summary of his dissertation for a candidate's degree in geological-mineralogical sciences. (Mosk. gos. un-t). Moscow, 22 pp.

62. ISRAFILOVA, A. YU. 1961. Thermal region of soils in the Nakhichevan ASSR. Dokl. (Akad. Nauk AzSSR). 17 (3):229-232. Bibliog. 6 refs. Summary in the Azerbaydzhan language.

63. Investigation of the Water Regime and Runoff Forecasts. 1961. (Collection of articles under the editorship of Sha. A. Kharshan). Tr. Tsentr. in-ta prognozov. No. 99. Moscow, Gidrometeoizdat. Mosk. etd. 132 pp. with diagrams and maps.

64. KUZAKOV, V. I. 1961. Effect of caterpillar and wheeled tractors on certain physical properties of soil. Tr. Stavropol'sk. s.-kh. in-ta No. 9:133-136.

BIBLIOGRAPHY

65. KUZ'MIN, V. A. 1960. Structure of forest and sod-calcareous soils in Irkutsk Oblast'. Author's summary of his dissertation for a candidate's degree in biological sciences. (Irkutsk. gos. un-t) Irkutsk. 20 pp.

66. KULAKOV, YE. V. and I. D. GROMYKO. 1961. Water-physical properties of chernozem soils in Kokchetav Oblast'. Dokl. TSKhA (Mosk. s.-kh. akad.). No. 60:69-76.

67. KUNIN, V. N. and G. T. LATSINSKIY. 1960. Temporary surface runoff and the artificial formation of ground water in the desert. Moscow, Izd. Akad. Nauk SSSR. 160 pp., with ill. Bibliog. pp. 154-159.

68. MUKHIN, V. M. 1961. Change of the water-physical properties of soils under the influence of freezing and thawing. Tr. Tsentr. in-ta prognozev. No. 113:71-94. Bibliog. 20 refs.

69. NIKOL'SKIY, N. N. 1961. Particle-size composition of sod-podzolic silty-clay loams under natural conditions and in a plowed field Dokl. TSKhA (Mosk. s.-kh. akad.). No. 60:85-91.

70. PROTOD'YAKONOV, M. M. 1960. Determination of maximum runoff of surface waters from small waterways. Leningrad, Gidrometeoizdat. 171 pp., with graphs. Bibliog. 55 refs.

71. RODE, A. A. 1960. Methods of studying the water regime of soils. (Pochv. in-t im. Dokuchayeva). Moscow, Izd. Akad. Nauk SSSR. 244 pp., with ill. Bibliog. pp. 239-243.

72. Improvement of the Physical Properties and the Nutrient Regime of Soils. 1961. (Collection of articles. Chief editor, N. K. Krupskiy). (Ukr. n.-i. in-t pochvovedeniye, Nauchn. trudy. Vol. 5). Izd. Ukr. akad. s.-kh. nauk. Kiev. 231 pp. with ill.

73. SHAFIBEKOV, A. V. 1960. Determination of the solid residue in ground water and water extracts from the soil by their specific gravity. Kirovabad. 50 pp.

74. BABEL, U. 1960. Untersuchungen an dem Janertschen Gerät zur Messung der Luftdurchlässigkeit von Böden im Gelände. Z. Pflanzenernähr., Düng., Bodenkunde, 91 (136) No. 1, 14-21.

75. BADEN, W., H. SEGEBERG. 1960. Untersuchungen über die Einwirkung von Grundwasserabsenkungen auf den Wasserhaushalt von Moor. und Anmoorböden der Erftniederung Wasser und Boden 12 (10):360-66.

76. BREITENÖDER, M. 1961. Grundwasserentnahme und Bodenwasserhaushal. — Österr. Wasserwirtsch. 13(5/6):90-93.

77. GÄTKE, C. R. 1960. Untersuchungen über den Einfluss des unbelebten organischen Bodenmaterials auf die Stabilität Von Bodenkrümeln gegenüber Wasser. Albrecht-Thaer-Archiv. 4(8):583-96.

78. GERTH, A. 1961. Die Wechselwirkungen zwei Braunerden mit unterschiedlichem Profilaufbau. Z. Ackerund Pflanzenbau. 112(3):292-302.

79. GÖTTLICH, K., U. RABEL. 1960. Einige Versuche zum bodenphysikalischen Verhalten der Anmcore Z. Pilanzenernähr., Düng. Bodenkunde, 90 (135), 3 243-54.

80. HENIN, S. et al. 1960. Le profil cultural. Principes de physique du sol. Paris, Soc. Ed. Ing. Agric. 320 p.

81. JOFFERY, P. C., A. D. WILSON. 1960. Closed-circulation systems for determining water. carbon dioxide and total carbon in silicate rocks and minerals. Analyst. No. 1015, p. 749-55. Bibliog. p. 754-55.

82. JOHNSON, D., K. AAS. 1960. Investigations of the technique of soil steaming. Stockholm, 69 p. Bibliog. p. 67-69. (Acta agric. scand. Suppl. 9).

83. MATTHEWS, O. R., Z. J. ARMY. 1960. Moisture storage on fallowed wheatland in the Great Plains. Soil Sci. Soc. America. 24, No. 5, p. 414-18.

84. PENROD, E. B. and others. 1960. Soil Sci. 90, No. 5, pp. 275-83 Bibliog. p. 282-83.

85. POEL, L. W. 1961. Soil aeration as a limiting factor in the growth of pteridium aquilinum (L.) Kuhn. J. Ecol. 49, No. 1, p. 107-11. Bibliog. 3 ref.

86. PUGH, A. L. and others. 1960. Modification of some physical characteristics of soils with VAMA ferric sulfate, and triphenylsulfonium chloride. Agron. J. 52, N 7, p. 395-402.

87. SIVADJIAN, J. 1960. Hygrophotographic measurement of soil moisture following a protracted drough. Soil Sci. 90 No. 6, p. 369-73.

88. STOECKELER, J. H., W. R. CURTIS. 1960. Soil moisture regime in Southwestern Wisconsin as affected by aspect and forest type. J. Forestry, 58, No. 11, p. 892-96.

89. THOMAS, A. C. 1960. A modified apparatus for the micro-determination of moisture in organic compounds. Analyst. 85, No. 1015 p. 771-72.

90. TORH, S. J., R. B. ALDERFER. 1960. Formation and breakdown of Co^{60} tagged water-stable soil aggregates in a Norton silt loam soil. Soil Sci. 90 No. 4, p. 232-38.

SOIL CHEMISTRY AND METHODS OF ANALYSIS

91. BUGAKOV, P. 1960. Data on the chemical characteristics of soils in slask fire and cut-over areas in certain regions of the sub-taiga and taiga zones. Tr. Karsnoyarsk. s.-kh. in-ta. Vol. 7:65-75.

92. BUGAKOV, P. Comparative evaluation of the results of the determination of adsorbed bases by various methods. Ibid. pp. 76-82.

93. BUGAKOV, P. and N. KAZANTSEV. Data on the chemical characteristics of soils in certain regions of the Kan forest-steppe and the adjoining sub-taiga. Ibid., pp. 49-64. Bibliog. 13 refs.

94. GORBUNOV, I. G. and N. V. SEROVA. 1961. Thermophysical characteristics and moisture of soils. Tr. Gl. geofiz. observ. No. 107:44-46.

95. DEBRITSKAYA, YU. I. 1961. Determination of available molybdenum in soils. Vestn. s.-kh. nauki. No. 6:109-116. Bibliog. 26 refs.

96. YEFIMOV, V. N. 1961. Forms of calcium and iron accumulation in peat beds. Dokl. Akad. Nauk SSSR. 138(2):435-436. Bibliog. 5 refs.

97. KOKOTOV, YU. A., R. F. POPOVA, and A. P. URBANYUK. 1961. Sorption of long-lived fission products by soils and clay minerals. 1. Radiokhimiya. 3(2): 199-206. Bibliog. 12 refs.

98. MAY, A. V. and N. YA. PARLASHKEVICH. 1961. High-frequency instrument for conductometry and titration. Plast. massy. No. 5:52-55.

99. MAKAROVA, G. 1961. Salt regime of the complex chestnut soils in the Sivash region. Vinogradarstvo i sadovodstvo Kryma. No. 5:52-55.

100. PEYVE, YA. V. 1960. Micro-elements and enzymes. (Akad. Nauk LatvSSR, In-t biol. Laboratoriya biokhim. i mikroelementov). Riga, Izdat. Akad. Nauk LatvSSR. 136 pp. with ill.

101. RATNIKOV, A. I. 1961. Available phosphorus content in the chernozems of the Tula Oblast'. Dokl. TSKhA (Mosk. s.-kh. akad.). No. 60:131-135. Bibliog. 6 refs.

102. SLAVINA, T. P. and L. M. BURLAKOVA. 1961. Nature of the accumulation of available forms of nitrogen in water-stable macroaggregates removed from the soil. Nauchn. dokl. vyssh. shkoly. Biol. nauki. No. 2:226-231. Bibliog. 7 refs.

103. AGARWAL, R. R. 1960. Potassium fixation in soils. Soils and Fertilizers, 23, No. 6, p. 375-78.

104. ANDERSON, G. 1960. Factors affecting the estimation of phosphate esters in soil. J. Sci. Food and Agric. 11, No. 9, p. 497-503.

105. BARROWS, H. L. and others. 1960. Effect of soil type on mobility of zinc in the soil and its availability from zinc sulfate to tung. Soil Sci. Soc. America Proc. 24, No. 5, p. 367. 72 Bibliog. p. 371-72.

106. BREMNER, J. M. 1960. Determination of nitrogen in soil by the Kjeldahl method. J. Agric. Sci. 55, pt. 1, p. 11-33.

107. BREMNER, J. M., D. S. JENKINSON. 1960. Determining of organic carbon in soil. 1. Oxidation by dichromate of organic matter in soil and plant materials. 2. Effect of carbonized materials. J. Soil Sci. 11. No. 2, p. 394-408. Bibl. p. 402, 407, 408.

108. CHAO, T. T. and oth. 1961. Sulfur movement in soils studied by tracer methods. Crops and Soils. 13, No. 5, p. 17.

109. CLARK, J. S., M. PEECH. 1960. Influence of neutral salts on the phosphate ion concentration in soil solution. Soil Sci. Soc. America Proc. 34, No. 5, p. 346-48.

110. CLARKSON, V. A. 1960. Effect of black polyethylene mulch on soil and micro-climate temperature and nitrate level. Agron. J. 52, N. 6, p. 307-09.

111. DATTA, N. P., M. B. KAMATH. 1959. Evaluation of soil tests for available phosphorus. Indian J. Agric. Sci. 29, Pt. 1, p. 11-18, Bibl. p. 17-18.

112. DAVIDESCU, D., E. GRUIA. 1960. Recherche électrométrique du système Al-Si-Ca. Agrochemica 4, (4):343-53.

113. GLASSER, F. P. 1961. The system Ca_2SiO_4 $-Mn_2SiO_4$. – Amer. J. Sci. 259, Jan. p. 46-59.

114. GORHAM, E. 1960. The pH of fresh soils and soil solutions. Ecology 41, No. 3, p. 563.

115. GORHAM, E. 1961. Water, ash, nitrogen and acidity of some bog peats and other organic soils — J. Ecology, 1961, 49, No. 1, p. 103-106. Bibliog. 15 refs.

116. KILMER, V. J., D. C. NEARPASS. 1960. The determination of available sulfur in soils. Soil Sci. America Proc. 24 No. 5, p. 337-40. Bibliog. p. 339-40.

117. KILNER, V. J. 1960. The estimation of free iron oxides in soils. Soil Sci. Soc. America Proc. 24, No. 5, p. 420-21.

118. Kinetik des Isotopenaustausches bei Phosphaten. 1. Untersuchungsmethode sowie graphische and rechnerische Auswertung Z. Pflanzenernähr. Düng., Bodenkunde, 91, (136) No. 3:224-32.

119. LETEY, J., A. KLUTE, 1960. Apparent mobility of potassium and chloride ions in soil and clay pastes. Soil. Sci. 90, No. 4, p. 259-65.

120. MACK, A. R., S. A. BARBER. 1960. Influence of temperature and moisture on soil phosphorus. 1. Effect on soil phosphorus fractions. Soil Sci. Soc. America Proc. 24, No. 5. p. 381-85.

121. MARKERT, S. A. 1960. Einige Versuche über die Beeinflussung der Bodendispersität durch K-und Ca-Jonen in Einzel- und Mischlösungen. Albrecht-Thaer-Archiv. 4(8):597-910.

122. PETER, H., S. MARKERT. 1960. Ein Beitrag zur Schnellbestimmung der Umtauschkapazität und des Sättigungsgrades von Ackerböden bei Serienanalysen. Z. landwirtsch. Versuchs- und Untersuchungswesen, 6(6):505-17. Bibliog. 7 ref.

123. PRATT, P. F., F. L. BAIR. 1961. Rapid method of estimating lime requirements of acid soils of California. Calif. Agric. 15, No. 1, p. 13.

124. RATHJE, W. 1960. Zur gegeseitigen Umwandlung von calciumgebundener Phosphorsäure und Aluminum- und Eisen (3)- ebundener Phosphorsäure in Boden. Plant and Soil, 13(2):159-65.

125. ROBINSON, J. B. D. 1960. Nitrogen studies in a coffee soil. 1. Seasonal trends of natural soil nitrate and ammonia in relation to crop growth, soil moisture and rainfall. J. Agric. Sci. 55, Pt. 3, p. 333-38.

126. SCHLICHTING, E. 1960. Die Phosphat- und Molybdat-Binding in raseneisensteinhaltigen Bodenprofilen. Z. Pflanzenernähr., Döng., Bodenkunde, 90 (135), No. 3:204-08.

127. STANCHEV, L. et al. 1960. Molybdenum and manganese in the soils of southern Bulgaria. Nauch. trudov Vissh. s.-g. in-ta "Vassil Kolarov". Vol. 8:157-172. Bibliog. 45 refs.

128. SWAINE, D. J., R. L. MITCHELL. 1960. Trace element distribution in soil profiles. J. Soil Sci. 11, No. 2, p. 347-68. Biblo. p. 367-68.

129. THOMAS, G. W. 1960. Effect of electrolyte imbibition upon cation-exchange behavior of soils. Soil Sci. Soc. America Proc., 24, No. 5, p. 329-32.

130. WELLS, N. 1960. Total elements in topsoils from igneous rocks: an extension of geochemistry. J. Soil Sci. 11, No. 2, p. 409-24. Bibliog. p. 423-24.

131. WERNER, W. 1960. Beitrag zur flammenspektrometrischen Magnesiumbestimmung mit dem Beckman DU Spektralphotometer Landwirtsch. Forsch. 3(4):273-77.

SOIL BIOLOGY AND MICROBIOLOGY

132. ABUTALYBOV, M. G. and N. I. GAZIYEVA. 1961. Influence of micro-elements on the development of the Azotobacter and on the activity of nitrogen-fixing micro-organisms in the soil. Uch. zap. (Azerbaydzh. un-t). Ser. biol. nauk. No. 1:45-53. Bibliog. 6 refs.

133. ABYZOV, S. S. 1961. Effectiveness of peat-manure composts in relation to the development of butyric bacteria in them. Mikrobiologiya. 30(3):489-493. Bibliog. 9 refs.

134. ALIYEV, S. A. 1961. Dynamics of the decomposition of plant residues under field conditions. Dokl. (Akad. Nauk AzSSR). 17(4):323-326. Bibliog. 5 refs. Summary in the Azerbaydzhan language.

135. ANDRIANOVA, T. M. 1960. Effectiveness of phosphobacteria on soils of the Omsk Oblast'. Omsk. 18 pp.

136. GELLER, I. A. and YE. G. KHARITON. 1961. Influence of herbicides on the soil microflora. Mikrobiologiya. 30(3): 494-499. Bibliog. 9 refs.

137. DANELIYA, M. K. 1961. Investigations on the microbiology of red earth soil. Subtropich. kul 'tury. No. 1-2:356-360. Bibliog. 7 refs.

138. DIMITROVA, N. A. 1961. Influence of various methods of soil tillage on the development of microbiological activity in it. Dokl. TSKhA (Mosk. s.-kh. akad.). No. 60:53-59.

139. DRAZNIYEK, YU. O. 1961. Oligonitrophic micro-organisms in the soils of the Murgaba oasis in Turkmeniya. Izd. Akad. Nauk TurkmSSR. Ser. biol. nauk. No. 1:3-11. Bibliog. 22 refs.

140. KALNIN'SH, A. D. 1961. Propagation of various breeds of nodule bacteria of clover in the soil and in the rhizosphere of clover and their participation in the formation of nodules. Tr. In-ta mikrobiologii Akad. Nauk LatvSSR. No. 14. Vopr. s.-kh. mikrobiol. 5:3-21. Bibliog. 13 refs.

141. KAMYSHKO, O. P. 1961. Soil fungi of the species Cephalosporium Corda. Botan. materialy Otd. spornykh rast. Botan. in-ta Akad. Nauk SSSR. Vol. 14:214-220.

142. KAPLUN, S. A. 1961. Azotobacter in irrigated soils and conditions for its effective utilization. Author's summary of his dissertation for a candidate's degree in biological sciences. (Tashkentsk. gos. un-t). Tashkent. 17 pp.

143. KLINTSARE, A. YA. 1961. Composition of aerobic microflora in the soils of natural meadows. Tr. In-ta mikrobiologii Akad. Nauk LatvSSR, No. 14. Vopr. s.-kh. mikrobiol. 5:65-75. Bibliog. 12 refs.

144. KRESLIN', D. YA. 1961. Change in the reaction (pH) of the nutrient medium depending on the growth intensity of local Azotobacter strains Tr. In-ta mikrobiologii Akad. Nauk LatvSSR. No. 14, Vopr. s.-kh. mikrobiol. 5:49-63. Bibliog. 11 refs.

145. LITVINOV, M. A. 1961. Study of soil micromyces in Central Kazakhstan. Botan. materialy Otd. sporovykh rast. Botan. in-ta Akad. Nauk SSSR. Vol. 14:232-241.

146. MAKAROV, B. N. and V. P. IGNATOVA. 1961. Biological activity of certain soil groups in the Soviet Union (according to the intensity of CO_2 production). Dokl. Akad. Nauk SSSR. 138(2):437-439. Bibliog. 11 Refs.

147. The role of Microorganisms in Reduction Processes in the Soil. Part 2. 1961. Duda, V. I. and L. V. Kalakutskiy. Reduction of iron by a pure culture of Pseudomonas tralucida. Nauchn. dokl. vyssh. shkoly. Biol. nauki. No. 2:198-201.

148. CHULAKOV, SHA. A. 1961. Microbiology of soils in Kazakhstan. Vestn. Akad. Nauk KazSSR. No. 5:3-9. Bibliog. 36 refs. Summary in the Kazakh language.

149. YAROVENKO, G. M. and S. I. ZAYKO. 1961. Regulation of biological processes of the transformation of phosphorus in sierozem soil. Dokl. Akad. Nauk UzSSR. No. 5:46-48. Summary in the Uzbek language.

150. BAROOAH, P. P., A. SEN. 1959. Studies on Beijerinskia from acid soils in India. Indian J. Agric. Sci. 29, No. 5, p. 36-51.

151. CAMERON, R. E., W. H. FULLER. 1950. Nitrogen fixation by some algae in Arison soils. Soil Sci. Soc. America Proc. 25, No. 5, p. 333-56. Bibliog. p. 356.

152. COIFIAIT, H. 1958. Les colépteres du sol. Paris, 204 p. Bibliog. p. 200-204. (Bull. du Laboratoire Arage. Suppl. 7. Actualite scientifiques et industirelles. No. 1260).

153. GOLLEY, F. B. 1960. An index to the rate of cellulose decomposition in the soil. Ecology, 41, No. 3, p. 551-52.

154. HENDERSON, V. E., H. KATZNELSON. 1961. The effect of plant roots on the nematode pepulation of the soil. Canad. J. Microbiol. 7, No. 2, p. 163-67. Bibliog. 15 ref.

155. HERR, L. J. and others. 1961. A soil dilution procedure applicable to rhizosphere micro-organism assays. Canad. J. Microbiol. 7, No. 2, 277-280. Bibliog. 4 refs.

156. MADAMBA, C. P. 1960. A practical method of collecting soil nematodes for population surveys — Philippine Agric. Engng. J. 44, No. 2. 146-48.

157. OLSON, G. W., I. M. McCALLA. 1960. A comparison of microbial respiration in soils. after a 20-year period of subtilling or plowing. Soil Sci. Soc. America Proc. 24, No. 5, p. 349-52.

158. RIVIERE, J. 1960. Le besoin en vitamines du groupe B des bacteries du sol. Ann. Agron. 11 (3):31-46.

159. STAPP, C. O. 1936. Zur Physiologie stickstoffbindender Mikroorganismen. Abstracts of communications (2nd Intern. congress for microbiology. London, 25 July — 1 August. 1936). London, p. 146-47.

160. SZEMBER, A. 1960. Influence on plant growth of the breakdown of organic phosphorus compounds by micro-organisms. Plant and Soil. 13, No. 2, p. 147-58. Bibliog. p. 157-58.

161. WILSON, P. W., E. B. FRED. 1936. Studies in the mechanism of symbiotic nitrogen fixation. In: Abstracts of communications (2nd Intern. congress for microbiology. London, 25 July — 1 August, 1936). London p. 148.

162. YOSHIDA, F., E. ICHISHIMA. 1961. Studies on the proteolytic enzymes of black aspergilli. Pt. 6. Further studies on the specificity of crystalline aspergillus Saitoi protease. Agric. Biol. Chemistry. 25, No. 2, p. 102-35.

SOIL FERTILITY, FERTILIZATION, AND TILLAGE

163. AVUNDZHYAN, Z. S. 1960. Characterization of the soils of hay fields and pastures of the Razden (Akhtin) rayon of the Arm SSR and relationship to their basic improvement. Author's summary of his dissertation for a candidate's degree in agricultural sciences. (Armyansk. s.-kh. in-t). Yerevan. 20 pp.

164. Agricultural-Chemical Methods of Soil Investigation. Instructions for field and laboratory investigations. 1960. (A. V. Sokolov and others, editors). 3rd ed. revised and enlarged. (Akad. Nauk SSSR. Pochv. in-t). 555 pp. Albam with colored illustrations for diagnozing plant nutrition. Supplement to the article of K. P. Magnitskiy. 28 leaves.

165. ANDREYEV, B. V. 1961. Increasing the fertility of solonetzes and solonetzic soils. Saratov, Kn. izd. 39 pp. with ill.

166. ASROROV, M. T. 1961. Methods for the basic tillage of old-irrigated meadow-sierozem soils in the Gissar valley. Izv. Akad. Nauk TadzhSSR. Otd. s.-kh. i biol. nauk. No. 1:3-21. Bibliog. pp. 20-21. Summary in the Takzhik language.

BIBLIOGRAPHY

167. AFANAS'YEV, G. V. 1961. Agricultural-chemical characterization of soils of the Maritime Province sovnarkhoz. Dokl. TSKhA (Mosk. s.-kh. akad.). No. 60:111-116.

168. AFANAS'YEV, M. V. 1960. Study of individual elements of the corn fertilization system. Author's summary of his dissertation for a candidate's degree in agricultural sciences. (Ukr. akad. s.-kh. nauk). Kiev. 18 pp.

169. BAYTULIN, I. O. 1961. Problem of the dependence of soil fertility on the degree of root accumulation in perennial grass sowings. Dokl. Kazakhsk. akad. s.-kh. nauk. No. 1:3-10. Summary in the Kazakh language.

170. BALYABO, N. K., S. G. VASIL'YEVA, and T. P. LASUKOVA. 1961. Rates for nitrogen fertilizers in relation to nitrogen dynamics in the soil. Khlopkovodstvo. No. 6:13-18.

171. VLADYCHENSKIY, S. A. 1961. Salt and moisture regime after diking. Nauchn. dokl. vyssh. shkoly. Biol. nauki. No. 2:221-225.

172. Influence of the Prolonged use of Fertilizers on Soil Fertility and the Productivity of Crop Rotations. Results of numerous experiments by scientific-research institutions. 1960. (P. G. Naydin, editor). No. 1, 472 pp. with ill.

173. Problem of Land Management, of Qualitative Land Evaluation, and Geodesy in the Baltic Republics. Materials of the Intra-republican Production Conference on Problems of Land Management, Economical Evaluation, and Geodesy. 1960. V. R. Timofeyev, editor. Riga. 278 pp.

174. GOLETIANI, G. I. 1960. Effect of mineral fertilizers on soil properties and the production of tea plantations. Tbilisi. 153 pp. Bibliog. pp. 149-151. In Georgian.

175. GRIGOR'YEV, N. YA. 1961. Basic soil tillage with the conservation of stubble in the semi-arid regions of the Southeast. Dokl. TSKhA (Mosk. s.-kh. akad.). No. 60:25-29.

176. GUSSEYNOV, D. M. and YU. K. KAKHRAMANOV. 1961. Influence petroleum growth stimulants on the growth of roots and the yield of winter wheat. Dokl. (Akad. Nauk AzSSR). 17(2):131-135. Summary in the Azerbaydzhan language.

177. D'YAKONOVA, A. A. 1960. Change in the physical and chemical properties of ordinary chernozem at the West Siberian vegetable experiment station under conditions of vegetable-grass crop rotation. Author's summary of his dissertation for a candidate's degree in agricultural sciences. (Bashkir. s.-kh. in-t). Novosibirsk. 23 pp.

178. ZHELIGOVSKIY, V. A. 1960. Elements of the theory of soil-cultivating machines and the mechanical technology of agricultural materials. Tbilisi. Izd. Gruzinsk. s.-kh. in-ta. 146 pp. with ill.

179. IVANOV, P. K. 1961. System of soil tillage in steppe regions. Moscow Sel'khozgiz. 223 pp. Bibliog. pp. 217-221.

180. IGNATENKO, I. I. 1961. Improved methods of basic soil tillage in the chernozems of the Azov region. S. kh. Sev. Kavkaza. No. 6:37-39.

181. KAMALETDINOV, T. 1961. Nutrient and water regime of soils and the development of cotton under square-hill cultivation. Author's summary of his dissertation for a candidate's degree in agricultural sciences. (Tashkentsk. s.-kh. in-t). Tashkent. 19 pp.

182. KAPLUN, G. N. 1960. Investigation of the effect of soil properties on the wear of the working parts of soil cultivating machines. Minsk. Izd. Akad. s.-kh. nauk BSSR. 44 pp. with ill. Bibliog. 12 refs.

183. KARTSEV, YU. G. 1961. Comparative study of soil plowing with and without a moldboard in the thick chernozem of the Khar'kov Oblast'. Dokl. TSKhA (Mosk. s.-kh. akad.). No. 60:45-52.

184. KATSAS, M. M. 1961. Absorption of calcium by plants from the calcareous soil horizon. Vestn. s.-kh. nauki. No. 6:37-41. Bibliog. 6 refs.

185. LIPKIND, I. M. and L. P. BELYAKOVA. 1960. Problems of increasing soil fertility in Tadzhikistan. Papers presented at the session of the Academy of Sciences of the Tadzhik SSR, devoted to the fulfillment of the tasks set by the XXI Meeting of the Communist Party of the USSR. Izv. Akad. Nauk TadzhSSR, Otd. s.-kh. i biol. nauk. No. 2:29-41. Bibliog. pp. 39-40. Summary in the Tadzhik language.

186. NARTSISSOV, V. P. 1961. Cultivation of gray forest soils and chernozems in Gor'kiy Oblast' and in the Chuvash ASSR. (Gor'kovsk. s.-kh. in-t). Gor'kiy. 137 pp. 1 leaf of graphs. Bibliog. 148 refs.

187. OZHIGOV, YE. P., A. F. SKRIPCHENKO. et al. 1960. Micro-nutrient fertilizers — important resource for increasing the yield of agricultural crops in the Maritime Province. (Dal'nevost. fil. Akad. Nauk SSSR). Vladivostok. 35 pp.

188. PERSHINA, M. N. and V. T. DODOLINA. 1961. Change in the chemical and water-physical properties of light-chestnut soils in the Volga upland under the influence of agricultural reclamation. Dokl. TSKhA (Mosk. s.-kh. akad.). No. 60:123-129.

189. SEREDINSKAYA, YE. V. 1961. Study of various methods of autumn-plowing sod-

podzolic soil in the central non-chernozem belt. Dokl. TSKhA (Mosk. s.-kh. akad.) No. 60:35-43.

190. SEREDINSKAYA, YE. V. Problem of the fertility of genetic horizons in sod-podzolic soils. Ibid., pp. 93-98.

191. TYURIN, I. V. and V. K. MIKHNOVSKIY. 1961. Influence of green manure on the humus and nitrogen content in sod-podzolic soil. Izv. Akad. Nauk SSSR. Ser. biol. No. 3:337-351. Bibliog. pp. 350-351.

192. SHVEDAS, A. I. 1961. Copper content and the effectiveness of copper fertilizers on the soils of the Lithuanial SSR. Author's summary of his dissertation for a candidate's degree in agricultural sciences. (Litov. s.-kh. akad.). Kaunas. 23 pp.

193. ADAMS, S. N. 1961. The effect of sodium and potassium on sugar beet on the Lincolnshire limestone soils. J. Agric. Sci. 56, Pt. 2, p. 283-85. Bibliog. 4 refs.

194. BECKER, G. 1961. Vierjährige Bodenfeuchtuntersuchungen auf dem Dikopshofer Dauer-düngungsversuch. Z. Acker-und Pflanzenbau. 112(3):279-91 Bibliog. 9 ref.

195. BOYD, D. A. and oth. 1961. Fertilizer practice in England and Wales. 1. General features of fertilizer consumption 1956-1957. Emp. J. Experim. Agric. 29. No. 113, p. 35-44. Bibliog. 6 refs.

196. BRÜNE, FR. 1960. Die Grundwasserabsenkungen im linksrheinischen Erftgebiet und ihr. Einfluss auf die Ertragsfähigkeit der dortigen Lösslehmböden. Wasser und Boden. Einfluss auf die Ertragsfähigkeit der dortigen Lösslehmoböden. Wasser und Boden. 12(10):347-60.

197. EYLES, A. G. 1960. Nitrogen in tropical agriculture. Nature 186, No. 4729, p. 941-42.

198. HANNEMANN, W. 1961. Die physikalischen Reaktionen in den Weinbergsböden unter Berücksichtigung der Wüngung vor und nach einer Neuanlage. Dtsch. Weinbau. 16(2):87-89.

199. JONES, W. W., T. W. EMBLETON. 1961. Leaf analysis as a guide to nitrogen fertilization of oranges. Calif. Agric. 15 No. 1, p. 14.

200. NÖSBERGER, J. 1961. Fragen der Erhaltung der Bodenfruchtbarkeit. Schweiz. Landwirtsch. Mn. 39:16-21.

201. POULSEN, E. 1959. Nitrate fertilization by means of ion exchange. Physiologia Plantarum, 12, No. 4, p. 826-33. Bibliog. 5 refs.

202. RICHARDSON, H. L. 1961. Fertilizers and food production. 2. How food production has been multiplied in certain countries. World Crops. 13, No. 3, p. 92-94.

203. SCHWARZ, P. et al. 1961. Über die Möglichkeit einer quantitativen Wertbestimmung gewisser Nährbodenarten und Nährboden bestandteile. Ztrblatt Bakter., Parasit., In fekt. Hygiene. 181(2):257-63.

204. Soil improvement. Crops and Soils. 1961, 13, No. 6, p. 22-23.

205. STOJKOVSKA, A. 1958. Chemical properties of lime from the saturation process and its effect on the nutrients in the soil. Zemljiste i Biljka, 7(8), No. 2, 3 p. 407-19.

206. STRATULA, V. et al. 1961. Contributii la studiul influentei ingrasamintelor organice penisipurile din Oltenia. Probl. Agric. No. 2;21-30. Bibliog. 8 refs.

207. TEUSCHER, H., R. ADLER. The soil and its fertility. London, W. Y. 446 p. (Reinhol Publ. Corporation).

208. The availability of Potassium in Some Tasma ian Soils. 1. The variability of soil potassium in the field and its fractionation. 2. Exhaustive cropping in relation to potassium reserves in the soil 1960. Austral. J. Agric. Res. 11. No. 5, p. 750-804. Bibliog p. 772-73.

209. WEBSTER, G. R., R. M. ADAMSON. 1960. Effects of saw-dust used as a mulch and as a soil amendment on soil temperatures under irrigated and unirrigated conditions. Canad. J. Soil Sci. 40 No. 2, p 207-11.

SOIL MELIORATION

210. AFANAS'YEV, G. V., I. A. DANILOV, and A. D. KASHANSKIY. 1961. Reclamation of bog soils in the north of the Arkhangel'sk Oblast'. Dokl. TSKhA (Mosk. s.-kh. akad.). No. 60:108-110.

211. BEL'SKIY, A. L. and A. G. NIKITIN. 1961. Melioration and earning capacity of sovkhozes. Sovkhoz. proizvodstvo. No. 6:50-54.

212. VLADYCHENSKIY, S. A. 1960. Practical uses in soil melioration. Moscow, Izd. Mosk. un-ta. 166 pp. with ill. Bibliog. 32 refs.

213. Hydraulic Engineering and Melioration. 1960. (S. A. Aver'yanov and others, editors). (Dokl. TSKhA. No. 56). Moscow 599 p. with ill.

214. KOSSOV Experimental Bog Station. (Brest Oblast'). 1960. Sb. nauchn. trudov. No. 1. (Akad. s.-kh. nauk BSSR. N.-i. in-t melioratsii i vodn. kh-va). Minsk. Izd. Akad. s.-kh. nauk BSSR 96 pp. with Ill.

215. KOSTIN, I. S. 1961. Basin irrigation in the

Trans-Volga region. Vestn. s.-kh. nauki. No. 6:83-94, With maps.

216. LEGOSTAYEV, V. M. 1960. Melioration of saline lands. Tashkent, Sred. i vyssh. shkola. 159 pp. with ill. In the Uzbek language.

217. Methodological Instruction for the Determination of the Stability of Mole Drains in Mineral Soils (Rosgiprovodkhoz). 1960. Moscow. 12 pp. with ill.

218. MOTSERILIYA, A. V. 1961. Investigation of problems of the drainage and reclamation of the Kolkhida lowland. Subtropich. kul'tury. No. 1-2:250-261.

219. PANFILOV, V. 1961. Reclamation of solonetzes. S. kh. Sibiri. No. 6:15-16.

220. Let us Change Bogs Into Productive Land. 1960. Ye. Ye. Alekseyevskiy, editor. Compiled by A. I. Gorskiy and A. I. Nasushkin. Kiev, Gossel'khozizdat UkSSR. 232 pp. with ill. In Ukrainian.

221. Fifty Years of Research work on the Cultivation of Bogs in Estonia. 1960. (Collection of articles). (Estonsk. n.-i. in-t zemledeliya i melioratsii). Tallin, Estgosizdat. 358 p. with ill. In Estonian. Summary in Russian.

222. RASULOV, A. 1961. Experimental reclamation of saline lands. (Reclamation of lands in Fergana). Tashkent, Gosizdat UzSSR. 40 pp.

223. System of Meliorative and Agricultural Practices for the Reclamation of Irrigated lands in the Rostov Oblast' 1960. Rostov-on-the-Don, Kn. izd. 163 pp. with ill.

224. TEYMUROV, K. G. 1961. New complex ameliorator for the forced melioration of solonetzes and sodium sulfate solonchaks. Dokl. (Akad. Nauk AzSSR). 17(2):137-140. Bibliog. 6 refs. Summary in the Azerbaydzhan language.

225. CHKHENKELI, I. A. 1960. Agricultural melioration. 4th revised ed. Tbilisi. Izd. Gruzinsk. s.-kh. in-ta. 301 pp. with Ill. In Georgian.

226. GARRELS, R. M. and oth. 1961. Control of carbonate solubility by carbonate complexes. Amer. J. Sci. 259, Jan. p. 24-45.

227. DOMSCH, M., D. SCHLÜNSEN. 1961 Zur technischen Durchführung der Sandbodenmelioration. Dtsch. Landwirtsch. 12(2): 66-68 Bibliog. 2 ref.

228. WOHLRAB, B. 1960. Ein Beitrag zur Frage über die Auswirkung wasserwirtschftlicher Eingriffe auf die Bodenentwicklung. Z. Pflanzenernähr., Düng. Bodenkunde 90 (135), No. 3:193-204.

SOIL EROSION AND ITS CONTROL

229. ALEKPEROV, K. A. 1961. Soil erosion in Azerbaydzhan and its control. Baku, Izd. Akad. Nauk AzSSR. 220 pp. with ill. Bibliog. pp. 210-219. In the Azerbaydzhan language. Summary in Russian.

230. BABAYEV, A. G. 1961. Conference on soil erosion control. (Moscow Dec. 1960). Izv. TurkmSSR. Ser. biol. nauk. No. 1:86-87.

231. BOCHAROV, A. P. 1961. Problem of measuring the sensitivity of soil to wind erosion. Dokl. Kazakhsk. akad. s.-kh. nauk, No. 1:71-75. Bibliog. 8 refs. Summary in the Kazakh language.

232. BYCHKOV, V. I. 1961. Linear erosion in the northern part of the Ust'-Ordynsk Buryat National Okrug, Irkutsk Oblast'. Izv. Sib. etd. Akad. Nauk SSSR. No. 3:90-97, with maps. Bibliog. 14 refs.

233. GAVRIK, P. A. 1960. Soil erosion control in the Trans-Carpathians. Uzhgorod, Zakarpatsk. obl. kn-gaz. izd. 62 pp. with ill. In Ukrainian.

234. IOVENKO, N. G. 1960. Soil erosion and its control. (Ukr. n.-i. gidrometeorol. in-t). Kiev. 24 pp.

235. How to Control Erosion. Instructions on Soil Erosion Control and the Productive Utilization of Eroded Lands in the Kolkhozes of the Poltava Oblast'. Poltava, Kn.-gaz. izd. 33 pp. In Ukrainian.

236. SOBOLEV, S. S. 1960. Development of erosion processes in the European USSR and their control. Vol. 2. (Pochv. in-t im. Dokuchayeva, Akad. Nauk SSSR). Izd. Akad. Nauk SSSR. 248 pp. with ill. and 2 maps.

237. SOBOLEV, S. S. 1961. Soil erosion and its control. (Vses. o-vo po rasprostr. polit. i nauchn. znaniy). Moscow, "Znaniye". 48 pp.

238. SUNG MU-LAN. 1960. Physico-chemical properties of eroded soils in the Don basin (taking the Staro-Beshev rayon of Stalin Oblast' as an example). Author's summary of his dissertation for a candidate's degree in agricultural sciences. (Khar'kovsk. s-kh. in-t im. Vil'yamsa). Khar'kov. 22 pp.

239. FILIN, V. I. 1960. Regionalization of the Bryansk Oblast' by erosion. (Central basin of the Desna River). Tr. Bryanskogo tekhnol. in-ta. Vol. 9:131-139.

240. SHIKULA, N. K. 1960. Characterization of eroded soils of the Don basin by their agricultural production and ways of increasing their fertility. Author's summary of his dissertation for a candidate's degree in agricultural sciences. (Khar'kovsk. s.-kh. in-t im. Dokuchayeva). Khar'kov. 23 pp.

241. BISAL, F. 1960. The effect of raindrop size and impact velocity on sand-splash. Canad. J. Soil Sci. 40, No. 2, p. 242-45.

242. HORNER, G. M. 1960. Effect of cropping systems on runoff, erosion, and wheat yields. Agron. J. 52, No. 6, p. 342-44.

243. JACOBSON, P. 1961. Soil and water conservation. In: Agricultural engineers' handbook. N. Y. Toronto. London, p. 313-539.

244. LYLES, L., N. P. WOODRUFF. 1960. Abrasive action of windblown soil on plant seedlings. Agron. J. 52, No. 9, p. 533-36.

245. MOLDENHAUER, W. C., W. H. WISCHMEIER. 1960. Soil and water losses and infiltration rates on Ida silt loam as influenced by cropping systems, tillage practices and rainfall characteristics. Soil Sci. Soc. America Proc. 24, No. 5, p. 409-13.

FOREST SOIL SCIENCE

246. VAZHOV, V. I. 1961. Effect of forest belts on the water balance of the soil and the productivity of agricultural crops. Izv. Krymsk. otd. Geogr. o-va SSSR. No. 6:79-87. Bibliog. 11 refs.

247. DZHAFAROV, B. A. 1961. Dynamics of available nutrients in mountain-forest soils under oak forests at various altitudes. Dokl. (Akad. Nauk AzSSR). 17(3):237-241. Summary in the Azerbaydzhan language.

248. ZHEREBTSOV, V. G. 1961. Importance of trees in kolkhoz fields in the control of wind erosion. Lesn. kh-vo. No. 6:40-41.

249. KRAYEVOY, S. YA. 1961. Possibility of overcoming the "dead horizon" of drying by forest belts. Byul. Mosk. o-va ispyt prirody. Vol. 66. Otd. biol. No. 2:85-97. Bibliog. pp. 96-97.

250. MITIN, V. G. 1960. Influence of conifer plantations on certain properties of chernozem. Tr. Bryanskogo tekhnol. in-ta. Vol. 9:162-169.

251. PILEVSKIY, S. G. 1960. Influence of kolkhoz forests in areas with little forests on snow cover depth and the depth of soil freezing under their canopy. Tr. Bryanskogo tekhnol. in-ta. Vol. 9:24-30.

252. PYATETSKIY, G. E. 1961. Water regime of soils in concentrated clear-cut areas in Southern Karelia and methods of regulating it. Tr. Karel. fil. Akad. Nauk SSSR. No. 25:43-58. Bibliog. pp. 57-58.

253. RAKHMANOV, V. V. 1960. Hydrological role of forests in the European USSR. (Mosk. gos. un-t. Geogr. fak.). Moscow, 29 pp. Bibliog. 16 refs.

254. RIY, V. F. 1960. Soil moisture and the suction force of the leaves of woody plants. Tr. Bryanskogo tekhnol. in-ta. Vol. 9:285-289. Bibliog. pp. 288-289.

255. SOLOV'YEV, P. YE. 1961. Change in the physical properties of ordinary chernozems under the effect of forest vegetation. Nauchn. dokl. vyssh. shkoly. Biol. nauki. No. 2:232-237.

256. KHARITONOV, G. A. 1960. Agricultural melioration of the Central Russian plateau. Author's summary of his dissertation for a doctor's degree in agricultural sciences. (Mosk. s-kh. akad. im. Timiryazeva). Moscow. 43 pp.

257. KÜBLER, H. 1961. Aufforstungen der Steppen und Wüsten Südrusslands. Forstz. 16, (9):181-182.

258. RIECKE, F. 1961. Erfolge bei der Sämlingsanzucht durch Bodenentseuchung. Forstz. (9):174-75. Bibliog. 7 Ref.

259. SCHÖNBACH, H. 1961. Ergebnisse eines Anbauversuches mit Aspe (Populus tremula L.) auf gleyartigen Boden. Archiv Forstwesen. 10-(2):150-70. Bibliog. 3 ref.

260. STANSKIY, J. J. 1961. Weed control. soil moisture and loblolly pine seedling behavior. J. Forestry, 1961. 59, No. 4, p. 282-84, 289-90.

261. WILLSTON, H. L., McCLURKIN, D. C. 1961. Soil moisture-seedling growth relations in conversion planting of oak ridges to pine. J. Forestry. 59, No. 1, p. 20-23.

MISCELLANEOUS, HISTORY OF SOIL SCIENCE

262. Biology and Soil Science. 1960. (Collection. Chief editor, T. A. Zimin). (Akad. Nauk SSSR. Sib. otd. Sakhalinskiy compleksnyy n.-i. in-t. Tr. No. 9). Yu.-Sakhalinsk. 138 pp. with ill.

263. GERASIMOV, I. P. and M. A. GLAZOVSKAYA. 1960. Principles of soil science and soil geography. (Textbook for the geographical faculties of universities). Moscow, Geografgiz. 490 pp. with ill. and maps. Bibliog. pp. 473-475.

264. Intra-Oblast' Scientific Conference of Soil Scientists of the Central Chernozem Belt (April 15-17, 1959). 1960. Summaries of papers. (Voronezhsk. gos. un-t, Vses. o-vo pochvovedov pri Akad. Nauk SSSR. Voronezhsk. otd.). Voronezh, Izd. Voronez sk. gos. un-ta. 150 pp.

265. MERSHIN, A. P. and A. I. ZHUKOV. 1961. Soil investigations in the virgin sovkhoz "Krasivinskiy", Akmolinsk Oblast'. Dokl. TSKhA (Mosk. s.-kh. akad.). No. 60:77-83

266. Nil Petrovich Remezov (1899-1961). Obituary. 1961. Vestn. Mosk. un-ta. Ser. 6. Biologiya, pochvovedeniye. No. 2:76-79, with portrait.

267. SOKOLOV, N. N. 1961. Scientific work of the Chair of Soil Geography. Vestn. Leningr. un-ta. No. 9, Ser. biol. No. 2:156-157.

268. SUCHKOV, S. P. 1960. Soil mpa of the "Tashkent" kolkhoz. (O-vo po rasprostr. polit. i nauch. znaniy UzSSR). 36 pp. with ill. In the Uzbek language.

269. SHAFIBAYEV, A. B. and G. I. ASKAROV. 1960. Laboratory exercises in soil science. (Textbook for correspondence students of agricultural faculties). (Kom. vyssh. i sred. spets. obrazov. Soveta Ministrov AzSSR). Kirovabad. 53 pp. with ill.

270. BUCKMAN, H. O., N. C. 1960. The nature and properties of soils. N. Y. 567.

271. DAVIDSON, J. 1960. Minor elements in nutrition. Nature, 186, No. 4729, p. 939-41.

272. DUCHAUFOUR, P. 1960. Précis de pédologie. Paris, 438 p. Bibliog. p. 397-417.

273. DUFRENOY, M. J. 1960. La chimie agricole après Lavoisier. Compt. rend Acad. agric. France, No. 17; 1012-16.

274. EHRENDORFER, K. 1960. Ein Vergleich von Bodenuntersuchungsmethoden. Z. Pflanzenernähr., Düng., Bodenkunde, 91 (136), No. 2:97-114. Bibliog. pp. 113-114.

275. HEILIGMANN, W. 1961. Bodenuntersuchungen in Freien. Mikrokosmos, 50: 23-27.

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